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AEROSOL AND LIGHT EXTINCTION DATABASES FOR NORTH AMERICA AND EUROPE

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Washington University
St. Louis, MO 63130-4899

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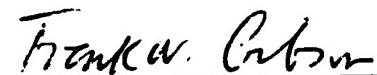


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<p>This report describes the databases assembled for the project "Climate and Properties of Atmospheric Aerosols." This database description (metadata) is provided to aid the data usage by other researchers. Applications of the database include atmospheric transmission models (e.g. LOWTRAN), global change studies, air pollution studies, and general contribution to atmospheric sciences. The four major aerosol databases include 1) Extinction coefficients for Europe (1977-1986) for 1,200 synoptic stations; 2) Extinction coefficient for North America (1948-1983) for 350 stations; 3) Aerosol mass and chemical composition data for 37 U.S. background stations; 4) Aerosol mass and chemical composition for the northeastern U.S. These primary databases are augmented by array of derived (filtered, aggregated, reconciled) databases. The data are provided both in portable ASCII form, as well as in efficient binary form. The binary data are suitable for browsing by the Voyager data browser which is supplied with the data set.</p>			
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1. INTRODUCTION

The transmission of electromagnetic radiation through the atmosphere is significantly hampered by the presence of atmospheric aerosols. Atmospheric dust and haze both scatter and absorb radiation in the visible and infrared region of the light spectrum, and tend to perturb human and electronic vision through the atmosphere.

Accounting for aerosol in models of electromagnetic transmission through the atmosphere is hampered by several factors: 1) Aerosol extinction covers both visible and infrared regions as a continuum without windows of high transmissivity. 2) Aerosol extinction has strong spatial and temporal variability, in many ways similar to that of water vapor. 3.) Aerosol are heterogeneous mixtures of different aerosol types, each type is contributed by different sources and possesses different properties. The main contribution of this study is to add to the above items, 2 and 3, by establishing the spatial and temporal pattern (aerosol climatology), and to quantify the contribution of different aerosol types.

In this study the derived aerosol climatology and aerosol types were obtained from the analysis of large data sets arising from atmospheric **measurements**. Such measurements include both optical data (visibility observations), as well as aerosol chemistry and mass concentration data. The estimation of the contribution of aerosol types was accomplished by judicious use of these two distinctively different data sets.

We believe that the results of this study can be extended to the aerosol component of radiative transmission models such as LOWTRAN and FASTCODE. These models are used operationally within the AF, and their performance can be significantly improved by an aerosol climatological database and aerosol knowledge. More importantly, the extinction data sets presented here can be used as input data to the transmission models. Given a specific location and season, this data set can provide a realistic estimate for the extinction coefficient by aerosol type, geography, and season anywhere over North America and Europe.

1.1 Related Reports

This report is the final summary report presenting the results from the past four years of research as part of this contract. Other summary reports include the

"Organization, Access, and Exploration Facilities for Large Geophysical Databases", (September 22, 1989). It describes the data organization principles applied to the visibility and aerosol databases. The second report, *Visibility Data Filters for Europe* (April 14, 1990), contains a methodology for identifying and removing erroneous visibility data. The third report, *Composition of Aerosols Over the Continental U.S.* (July 12, 1991), partitions the aerosol mass into aerosol types then analyzes the spatial and season distribution of the aerosol types. The fourth report, *Apportionment of Light Extinction by Aerosol Types Over the U.S.* (October 1, 1991) combines the light extinction data from visual range observations with aerosol chemical composition data. The resulting aerosol extinction coefficients are apportioned by aerosol types. This final report is a description of the databases collected and used in the previous reports.

1.2 Scope of this Report

The main topic of this report is to describe the aerosol and related databases created or assembled during the current Aerosol Climatology project. The report contains:

- 1.) Lists the created databases.
- 2.) Documents the original data sources.
- 3.) Describes the data formats.

A key part of the report is a set of databases supplied on IBM compatible floppy disks. The data files are in self-describing, fixed-length ASCII format which is suitable for import into most PC, mini, and mainframe programs.

A unique feature of the supplied database is that it is provided with a graphic data browser software. The Voyager data browser by Lantern Corporation allows the display of extinction data on spatial maps and time charts. It is hoped that the easy data access will facilitate extended use of the database by other researchers interested in aerosol climatology. The databases derived from this project are providing significant input to global change studies. In particular, the Air Force supported data for Europe are integral part of the Global Aerosol Data System (GADS), supported by National Oceanic and Atmospheric Administration (NOAA) Global Change Data and Information System (GCDIS)⁽¹⁾.

The body of this report has four major sections:

2. Raw Data Sources
3. Haze Climate of North America
4. Haze Climate of Europe
5. Aerosol Composition over the U.S.
6. Summary

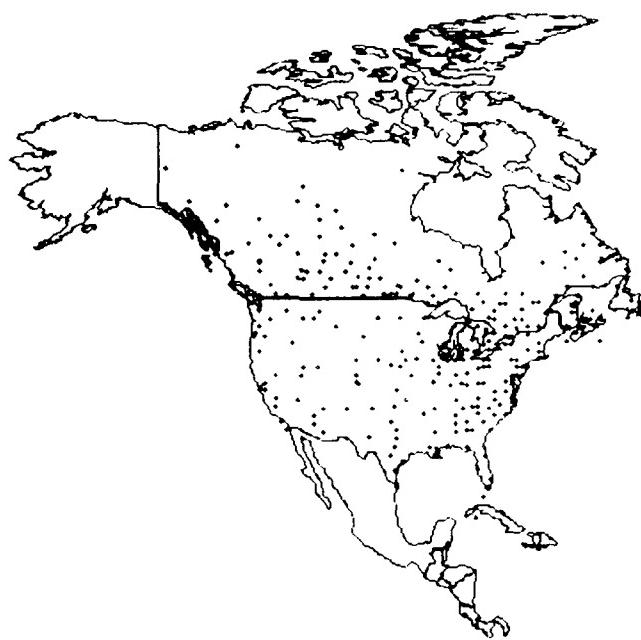
2. RAW DATA SOURCES

2.1 North American Light Extinction Database

The North American Light Extinction database, BEXTAMER, originated from more than 300 surface meteorological observations. This database is maintained at the Center for Air Pollution Impact and Trend Analysis of Washington University^(1,2). The location of the North American sites are shown in Figure 1. The initial database contained three hourly observations of all meteorological variables reported by synoptic stations. The reported noontime visual range measurements were converted to the horizontal extinction coefficient, b_{ext} using the Koschmieder relationship; $b_{ext} = \log(C)/V$ where C is the Contrast Threshold set to 0.02 and V is the visual range.

A problem with visual range measurements is that there is always a furthest marker beyond which the visual range is not resolved^(1,3). This translates to a lower threshold value for the computed extinction coefficient. For this reason, the mean is inappropriately biased upward, and more reliable, nonparametric statistical indices are more useful. Therefore, the data was placed into the 25th, 50th, 75th, and 90th cumulative distribution functions for each month and year.

The cumulative distribution functions were calculated for three different extinction coefficients. The first set (b_{ext1}) included all visibility data regardless of weather and pollutant conditions. The second group (Fb_{ext}) was calculated excluding any visual range measurements taken during precipitation (rain and snow) and fog events. The third (RHb_{ext}) group excludes precipitation, fog, and also performs an RH correction to compensate for water and vapor effects.⁽¹⁾ This latter parameter is closely related to the dry fine particle aerosol mass concentration. This data processing reduced the original data from over 50 magnetic tapes to a data set which fits on a floppy disk.



1. Location of the observation sites for the North American visual range database.

2.2 European Light Extinction Database

The original European data set consisted of fourteen years of meteorological data (1973-1986) for about 1600 stations in Europe. The location of each site is depicted in Figure 2. This data set was extracted from the DATSAV global weather database maintained by the U.S. Air Force, ETAC, Scott Air Force Base, IL.

The raw meteorological data set consisted of over 1000 magnetic tapes containing about 30 gigabytes of data. The first step in the data processing involved compacting the data set into a binary form which reduced the data size to a more manageable 3 gigabytes. Next, the noontime visual range was converted into the extinction coefficient using a contrast threshold of 0.05 in the Koschmieder equation. The data were then placed into the 10th, 25th, 50th, 75th, 90th, and 95th cumulative distribution percentiles for each quarter of the year. Quarter 1 begins in January.

The final data set contained a subset of the available meteorological variables: Raw Visibility, Dry Extinction Coefficient calculated by excluding any visual range measurements taken during precipitation (rain and snow) and fog events, Temperature,

Dew Point, Cloud Ceiling, and Past Weather. The 75th percentile of the Dry Extinction coefficient has also undergone considerable filtering to eliminate suspect data⁽³⁾.



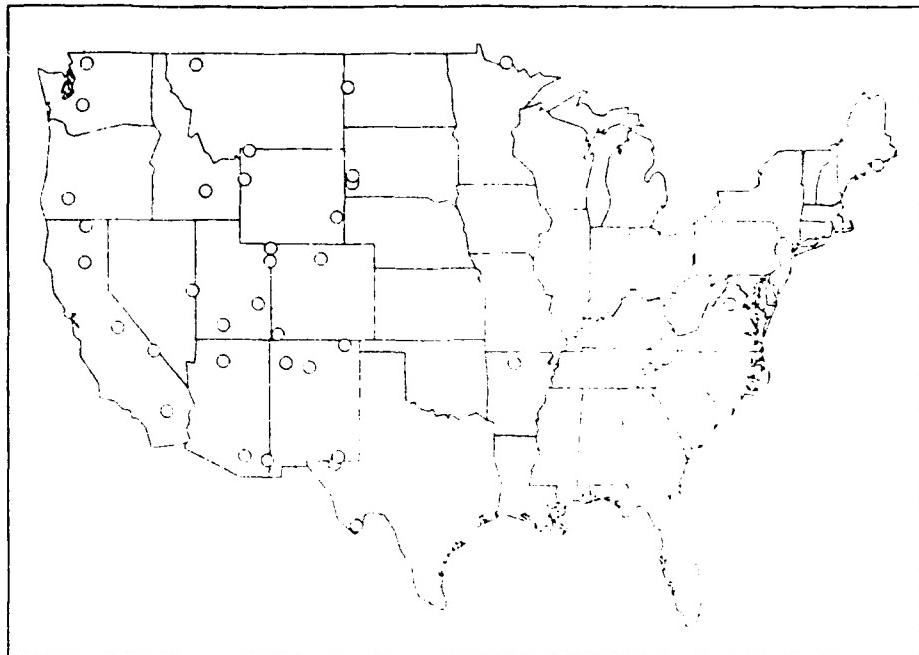
Figure 2 Location of the observation sites for the European visibility database.

2.3 NPS - NFPN Aerosol Chemistry Database

The National Park Service - National Fine Particle Network, NPS - NFPN, consisted of 37 stations located across the continental U.S., Figure 3. As shown, these stations were located primarily in the western U.S. with five sites in the east. All of the samplers were located inside national parks and wilderness areas far from any urban centers, industrial sources, and highways. Inside the parks the samplers were kept away from roads, parking lots, and chimneys.

The NPS-NFPN network which began operating in June 1982 originated from the Western Particulate Monitoring Network (WPMN). Several stations were added since the initial establishment of the NPS-NFPN network. This led to a station dependent sampling

Sampling Sites for NPS-NFPN Network



Sampling Sites for the NESCAUM Network

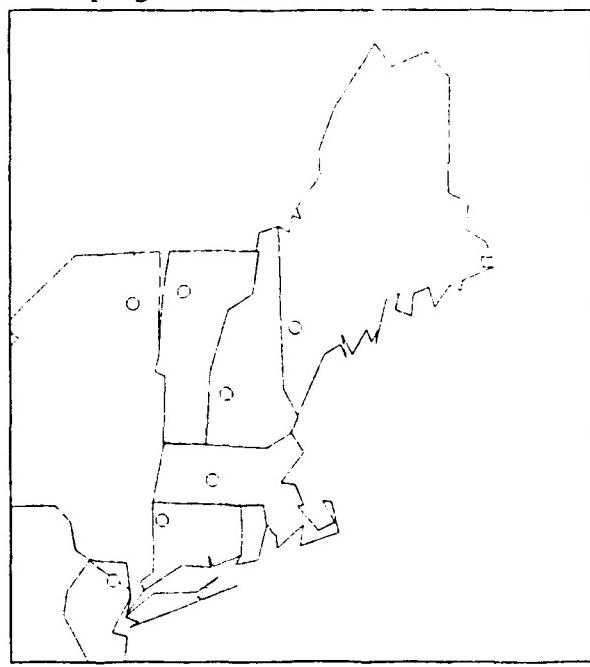


Figure 3. Location of the NPS-NFPN and the NESCAUM monitoring sites.

period for the database. However, most of the stations contained data from January 1983 to June 1986. Exceptions to this are for the three stations, Acadia ME, Voyageurs, MN, and Saquaro, AZ, which were added to the network in 1985. Upon examination of the raw data, a marked improvement in the quality of the raw data after 1983 was found.

Two samples each week were collected over a 72 hour duration using the AeroVironment SFS-500 samplers. The aerosol samplers collected both fine and coarse particles with approximately a 50% cut off ratio at $2.5 \mu\text{m}$ ⁽⁴⁾.

The chemical analysis of the aerosol samples was conducted at the University of California, Davis using four nondestructive techniques. These techniques measured the fine and coarse mass by gravimetrically weighing the samples; measured the optical absorption of the fine mass samples using a laser integrating plate method, IPM; measured the elemental concentrations for sodium to lead using a particle induced X-ray emission, PIXE; and measured the hydrogen content of the fine aerosol sample using a proton elastic scattering analysis, PESA⁽⁴⁾.

The NPS-NFPN network is no longer in operation. It has been superseded by the IMPROVE (Interagency Monitoring of Protected Visual Environments) monitoring network beginning in 1988.

2.4 NESCAUM Aerosol Chemistry Database

The NESCAUM network consists of seven stations located in the Northeast of the U.S., Figure 3. These sites are located in rural locations which were found to be consistent with EPA, NPS, and IMPROVE siting criteria⁽⁵⁾. The data spans a two year time period September 1988 to September 1990. This network is still in operation.

The fine particles were sampled for a 24 hour duration on every Wednesday, Saturday, and every 6th day. The fine particles were separated from the aerosol using a U. C. Davis cyclone sampler, and collected on Teflon filters mounted in nucleopore cassettes. This cyclone had a 50% capture efficiency for particles $2.5 \mu\text{m}$ in diameter at a flow rate of 23 l/min. The samples containing the fine mass were analyzed by the U. C. Davis laboratory. There the mass, absorption, hydrogen concentration and elemental

concentrations, sodium and heavier metals were analyzed using the same techniques as those used for the NPS - NFPN network⁽⁵⁾.

3. HAZE CLIMATE OF NORTH AMERICA

The haze climate of U.S. and North America was studied extensively over the past 15 years⁽¹⁻²⁾. A pictorial summary of the present North American haze atlas is given in Figures 4-11. The specific parameter that is plotted on the maps is the 75th percentile of extinction coefficient. While this is unconventional, it constitutes the safest approach in that it does not require any extrapolations or other adjustments to the data. More conventional statistical measures can be estimated as follows: from the previous research⁽¹⁾, the extinction coefficient is roughly log normally distributed with logarithmic standard deviation of 2.5. For such a distribution, the 50th percentiles is 0.5 times the 75th percentile, and the mean is 0.76 times the 75th percentile. Thus, if one is to convert the maps, the scales of the intervals must be multiplied by the appropriate fractions.

The climatic maps for two extinction parameters b_{ext} and Fb_{ext} are grouped, 4 maps each, representing four seasons. The time periods are selected to center around 1950, 1960, 1970, and 1980, while the four seasons are quarters January-March, April-June, July-September, and October-December.

Figures 4-7 show the 75th percentile coefficients for all data regardless of weather. The first quarter haziness depicts the worst visibility in the area surrounding the Great Lakes, while the best visibility in Arizona and New Mexico. Visibility region around the Great Lakes has changed somewhat in the 1948-1983 period: a decline was observed in the northeastern state (New York), and an increase in the upper midwest. The high b_{ext} in the polar regions of Canada does not have any plausible explanation. The increased visibility trend in the Dakotas may be, in fact, spurious, since there are no actual stations in those two states. However, the increase in Minnesota and Wisconsin is real, since it is based on three stations. There is also evidence of declining overall winter visibility in the Gulf states. The winter visibility in the Rocky Mountain states is rather varied: being best in the southern states Arizona and New Mexico, and declines with increasing latitude. Superimposed on this latitudinal trend are two hot spots, Salt Lake City, UT and Missoula, MT. These two sites stand out particularly in the 1955-1964 period. Undoubtedly, these are localized hot spots of winter haze caused by processes within their local environment. It is likely that if more stations were available, additional poor visibility hot spots would

show up. The visibility over the California-Oregon coast has evidently declined in the 1848-1983 period, but much of the increase has happened in the 1950s and little since then.

In the second quarter (April-June) a significant increase is exhibited over the United States east of the Rockies. The states west of the Rockies have not changed significantly. Around 1950, the low visibility region was confined to the Ohio and Mississippi Valleys. By the 1980s much of the eastern U.S. was covered with springtime haze.

The most significant changes are noted for the third quarter (July-September). Evidently the visibility in Southern California has improved, while the visibility in the southeastern states south of the Ohio River has declined.

The fourth quarter (October-December) haziness exhibits similar pattern to the first quarter, both qualitatively and quantitatively, the outstanding feature being the poor visibility over the west coast states and those surrounding the Great Lakes. It is also interesting to note the decline of haziness in the Great Lakes region since the 1970s.

Undoubtedly, the extinction coefficient shown in Figures 4-7 is strongly influenced by the occurrence of precipitation and fog. The role of these natural meteorological events is particularly important for quarters 1 and 4.

Well over half of the extinction coefficient is due to precipitation and fog in the Great Lakes and western states. On the other hand, the winter time extinction coefficient is not significantly influenced by precipitation and fog over the Gulf states. In addition to the removal of fog and precipitation events, additional correction is required for the noontime relative humidity effect. The results of the thus corrected maps are presented in the next section.

Data, excluding precipitation and fog ($F_{b,ext}$) The extinction coefficient in Figures 8-11 is indicative of the dry fine particle concentration over the continent. Hence it represents a "pollution index" for visual air quality. The winter season "dry" haziness is most pronounced over the Great Lake states, California, and the Gulf states. Pennsylvania and New York show declines of dry haze from the 1950s to the 1980s. Ohio has not changed significantly. The California stations, particularly in the south coast basin, show increase winter dry haze, particularly from 1940 to 1950. The most significant wintertime

increase is noted from the Gulf states, Louisiana, Alabama, Mississippi, and Georgia. Once again, the high F_{bext} values in northern Canada are to be noted.

Second and third quarter haziness show an increase over all states east of the Rocky Mountains. The increase is most pronounced for the Gulf states, and least over the northeast and California.

Quarter four closely resembles the spatial and temporal trends over the first quarter. Again, notable exceptions are the improved late fall visibility in the Ohio region.

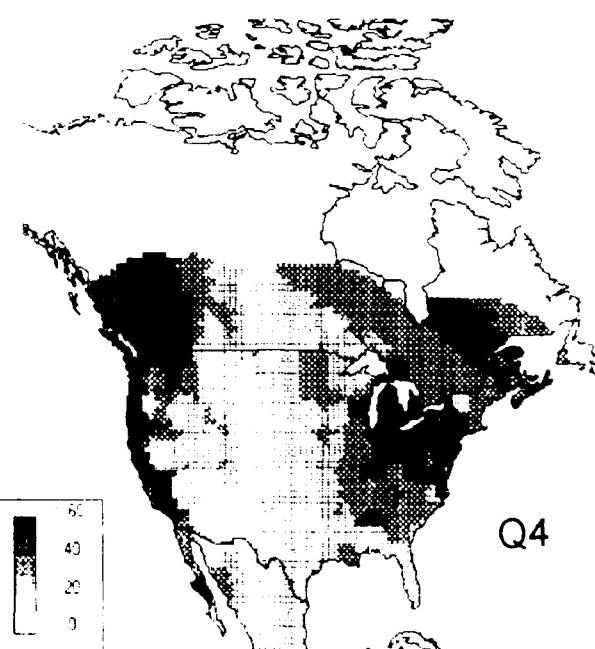
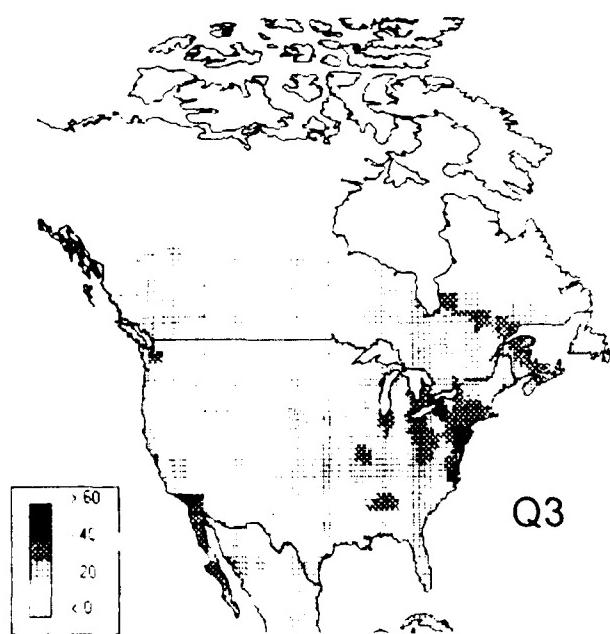
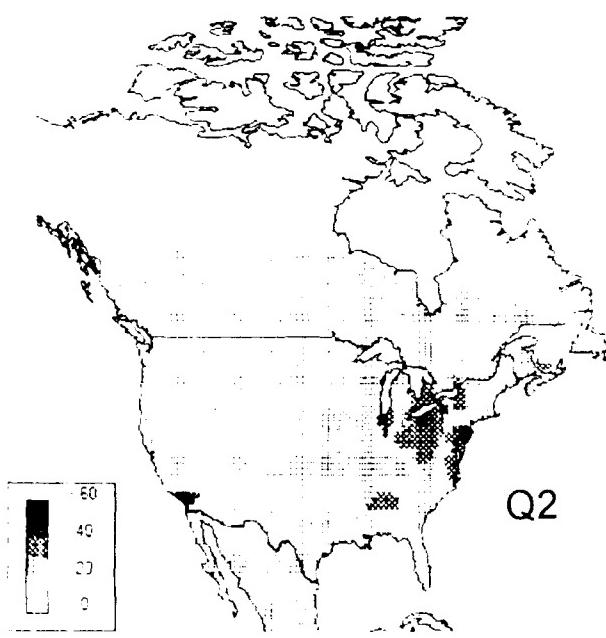
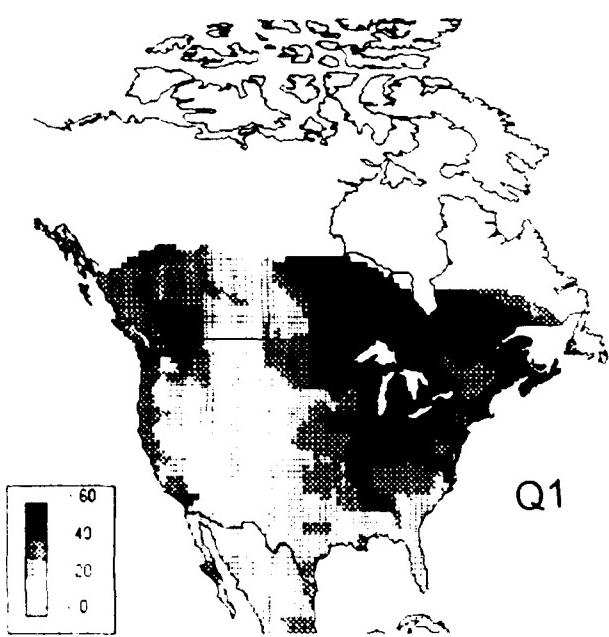
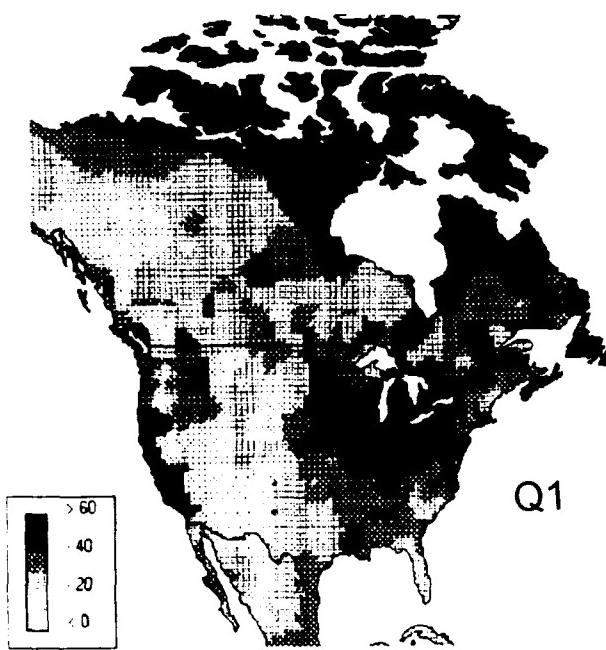
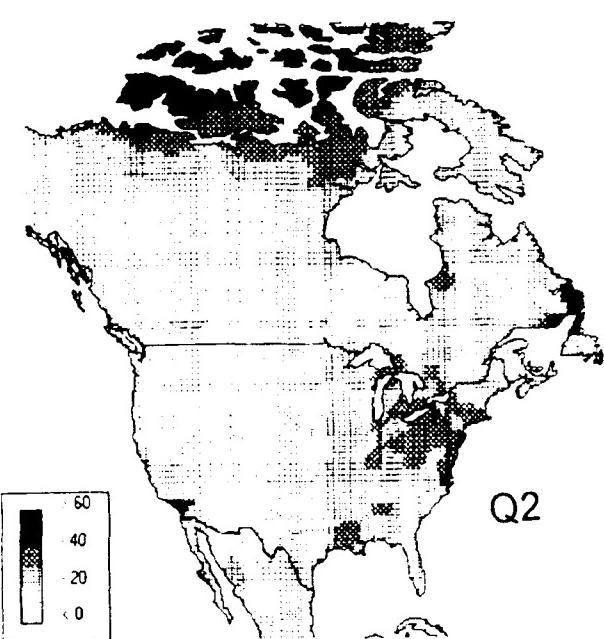


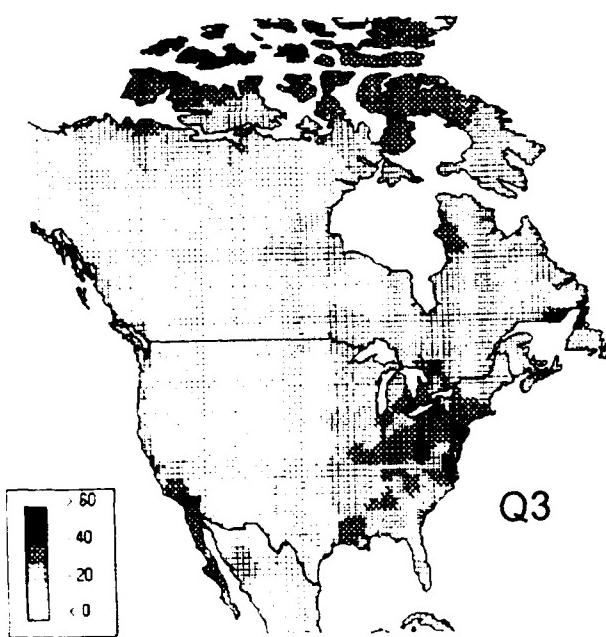
Figure 4 Quarterly maps representing 75th percentile for all data for the extinction coefficient around 1950.



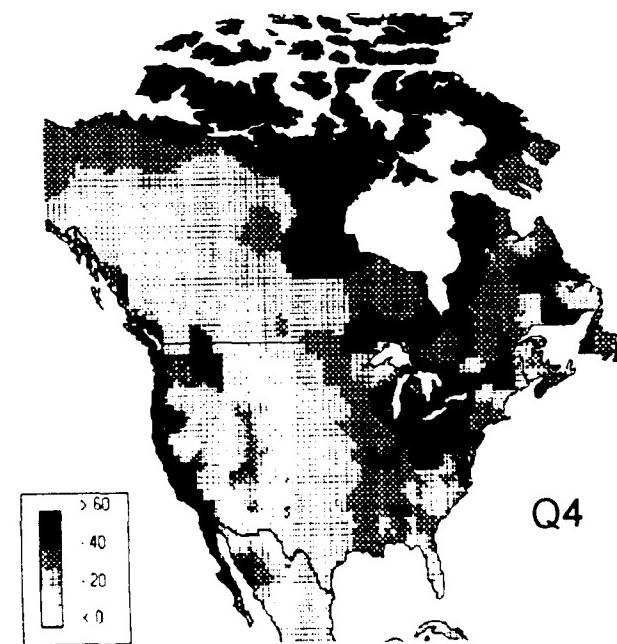
Q1



Q2



Q3



Q4

Figure 5 Quarterly maps representing 75th percentile for all data for the extinction coefficient around 1960.

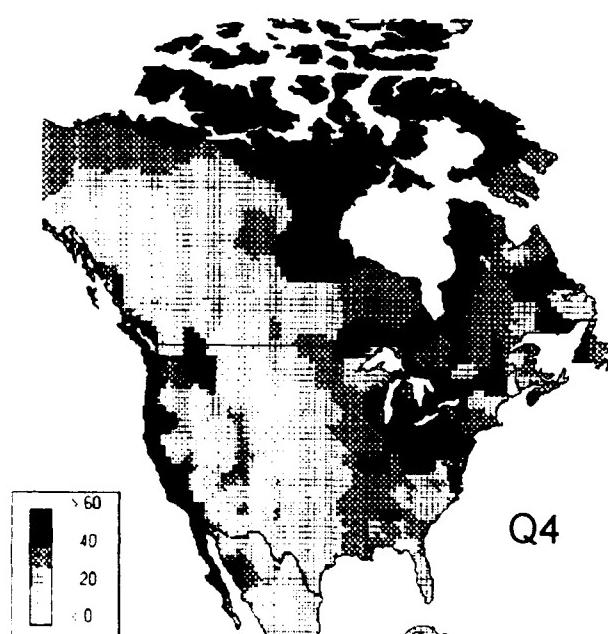
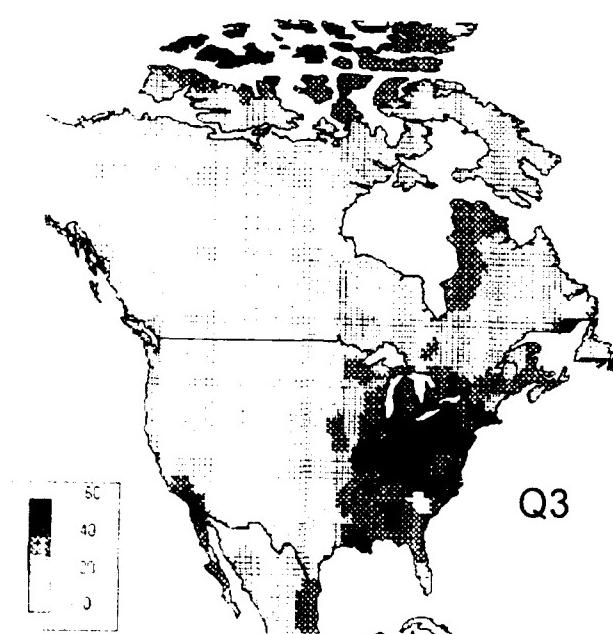
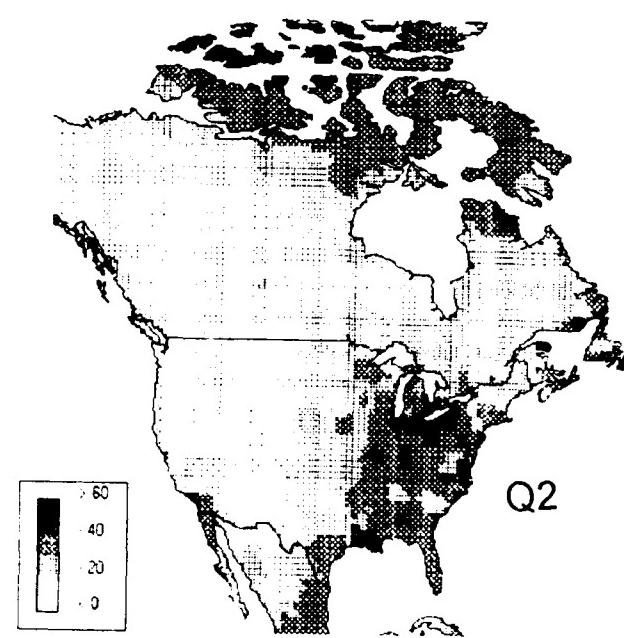
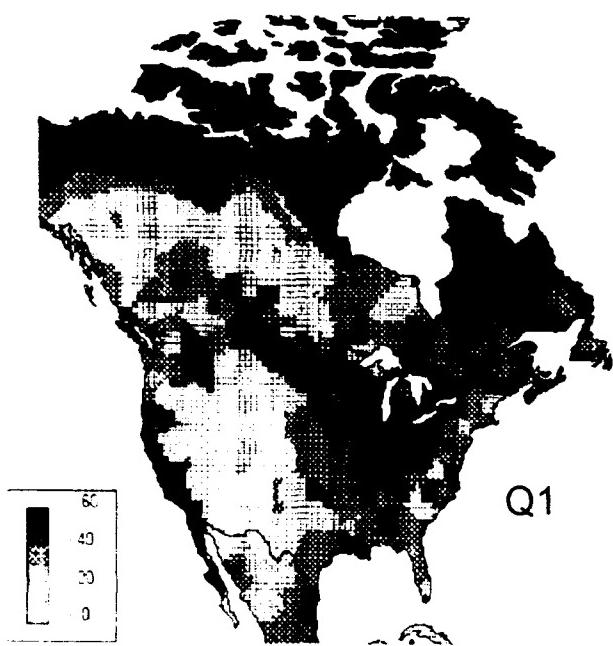
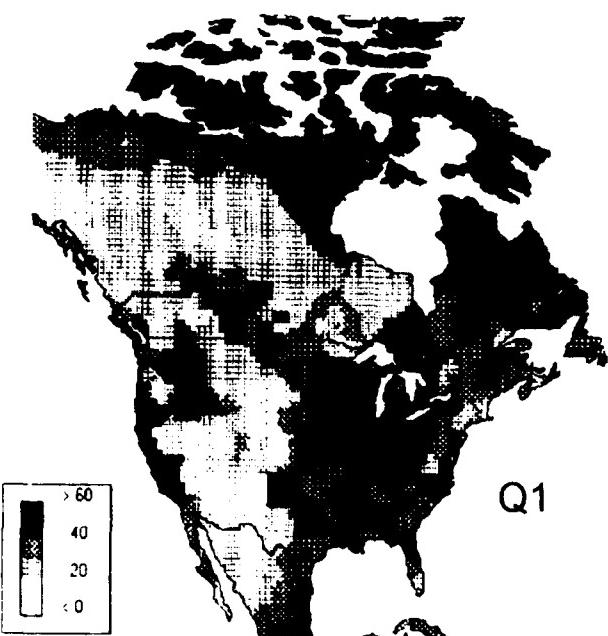
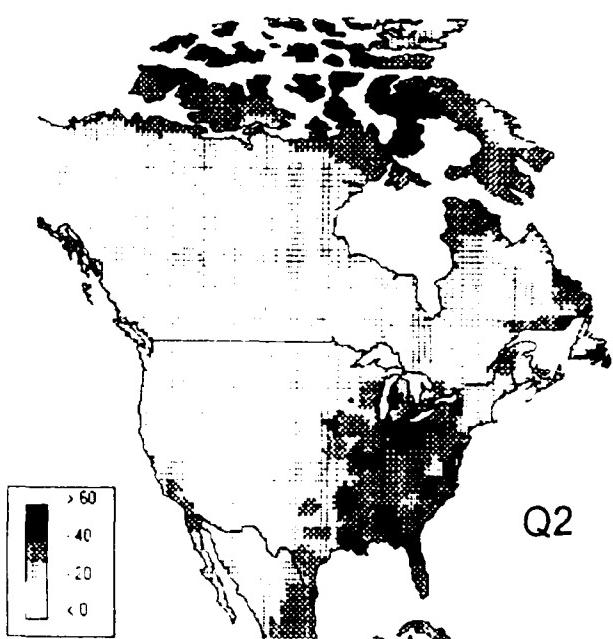


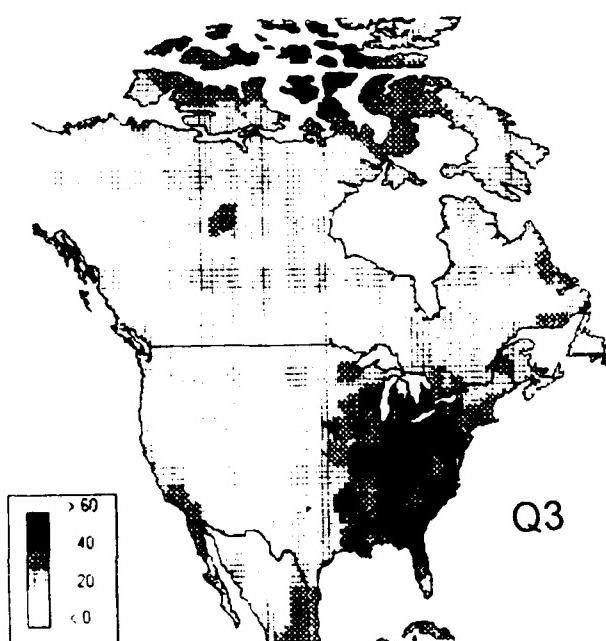
Figure 6 Quarterly maps representing 75th percentile for all data for the extinction coefficient around 1970.



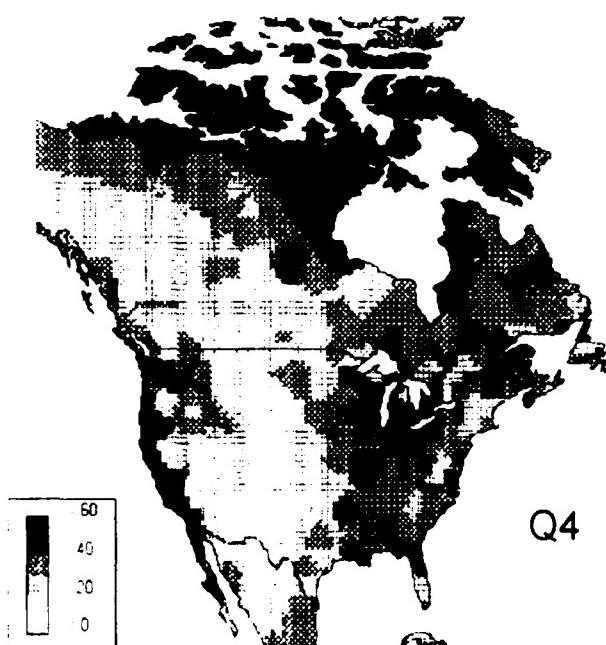
Q1



Q2



Q3



Q4

Figure 7 Quarterly maps representing 75th percentile for all data for the extinction coefficient around 1980.

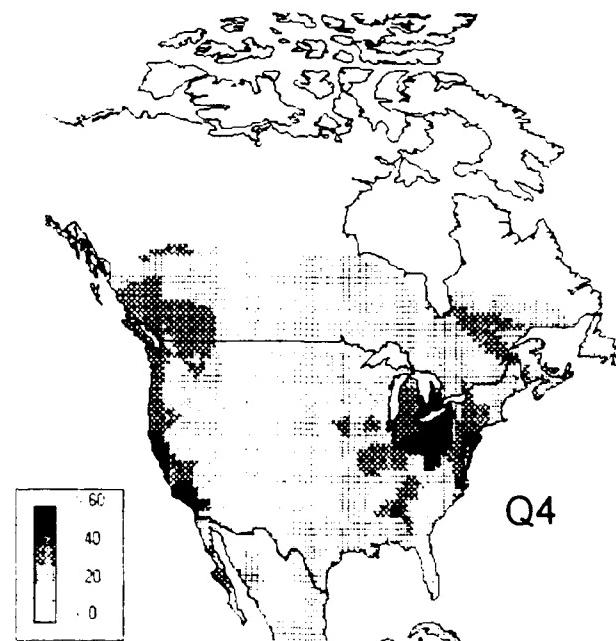
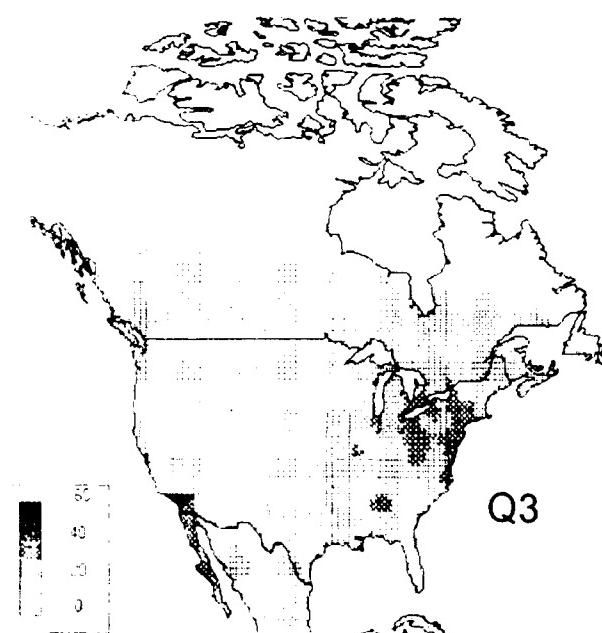
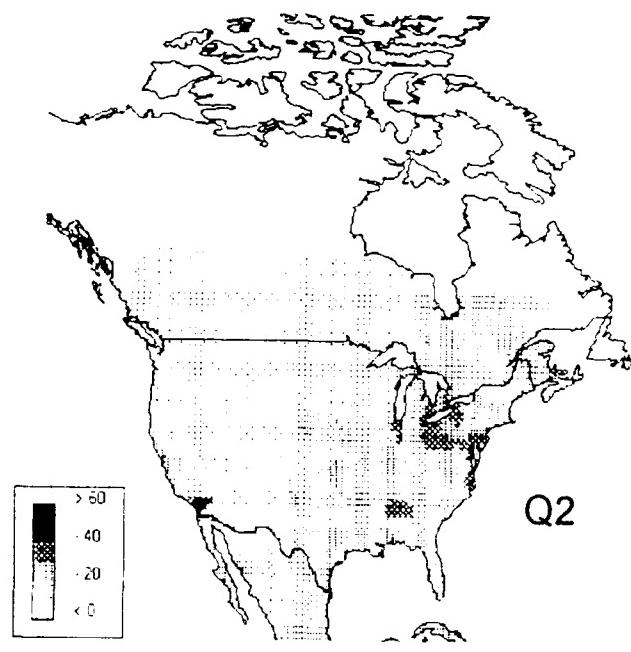
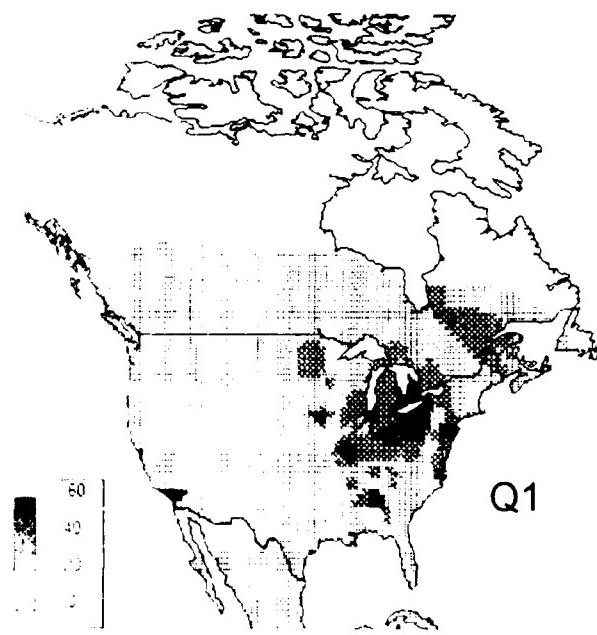


Figure 8 Quarterly maps representing filtered extinction coefficient for fog and precipitation, Fb_{ext} , around 1950.

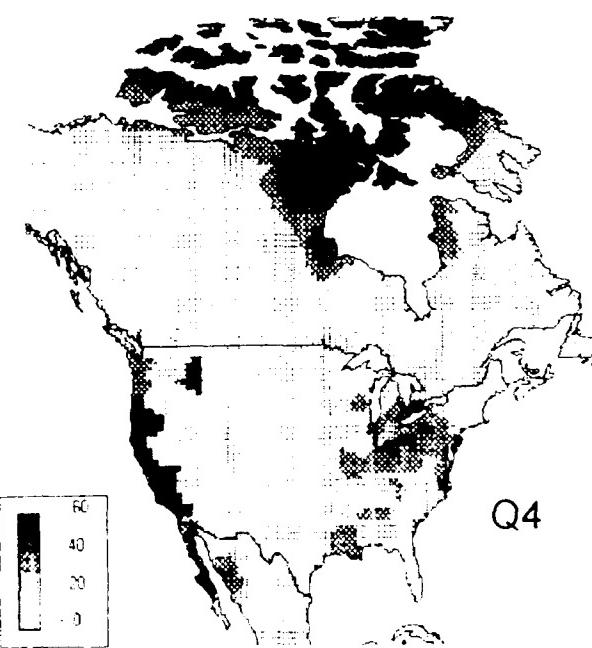
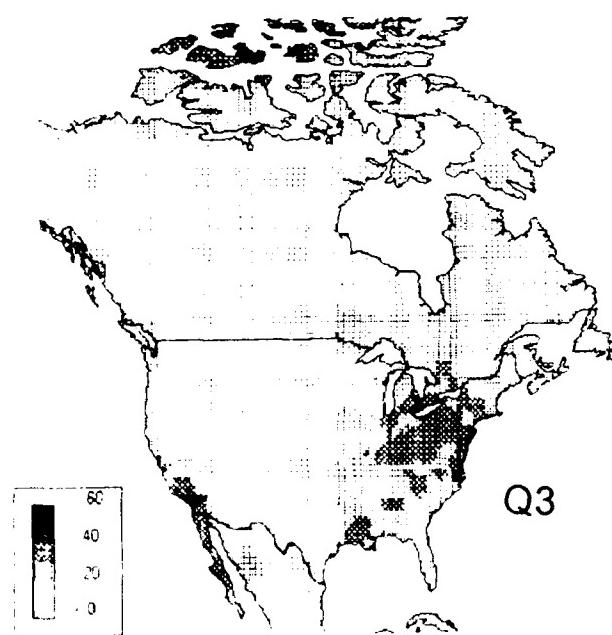
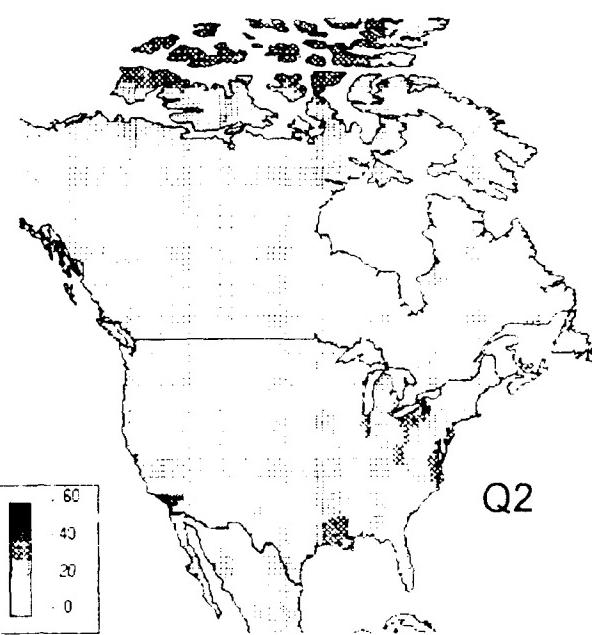
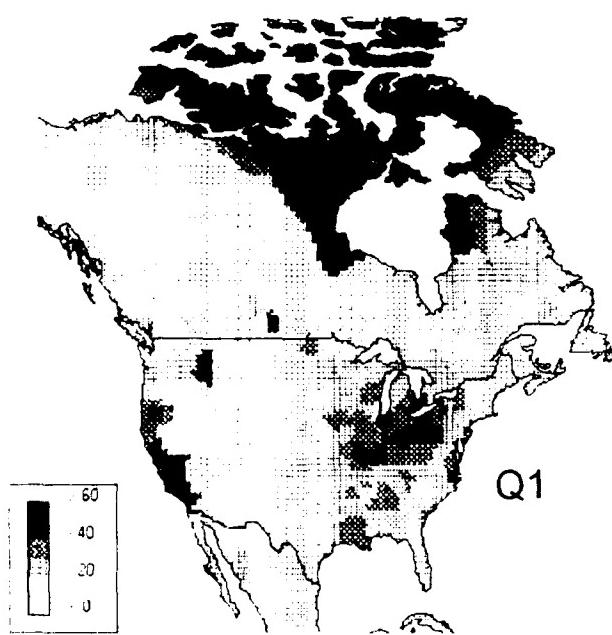
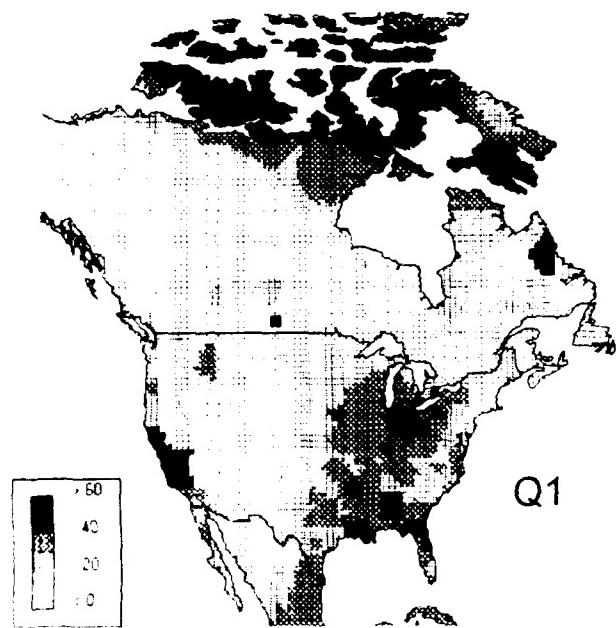
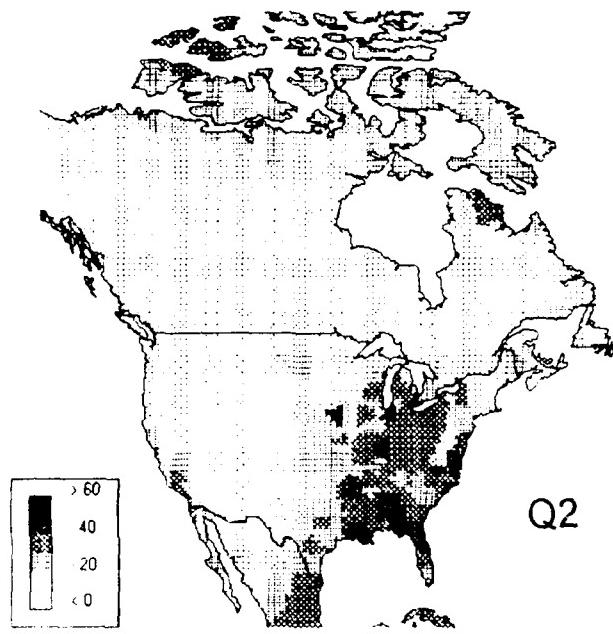


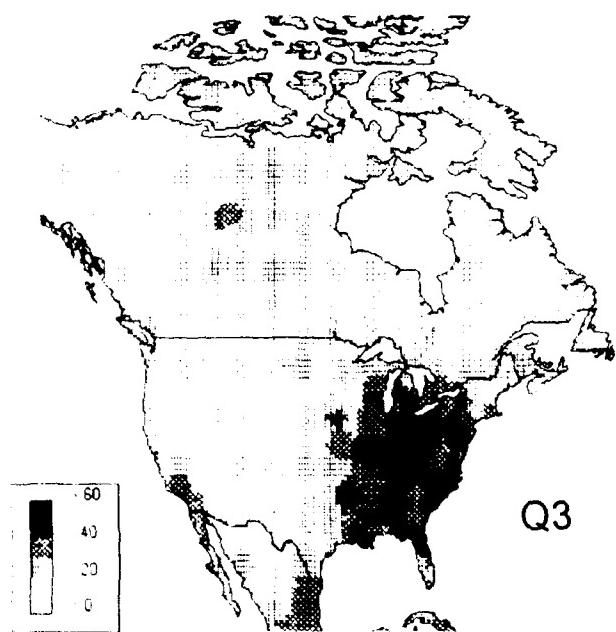
Figure 9 Quarterly maps representing filtered extinction coefficient for fog and precipitation, $F_{b\text{ext}}$, around 1960.



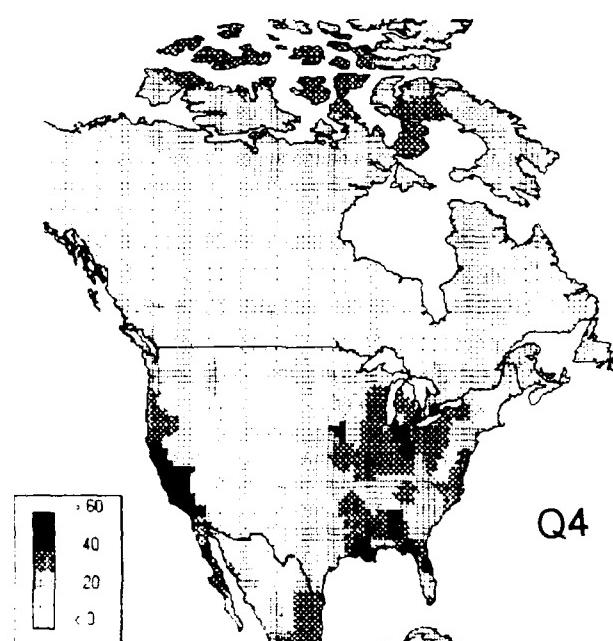
Q1



Q2



Q3



Q4

Figure 10 Quarterly maps representing filtered extinction coefficient for fog and precipitation, $F_{b_{ext}}$, around 1970.

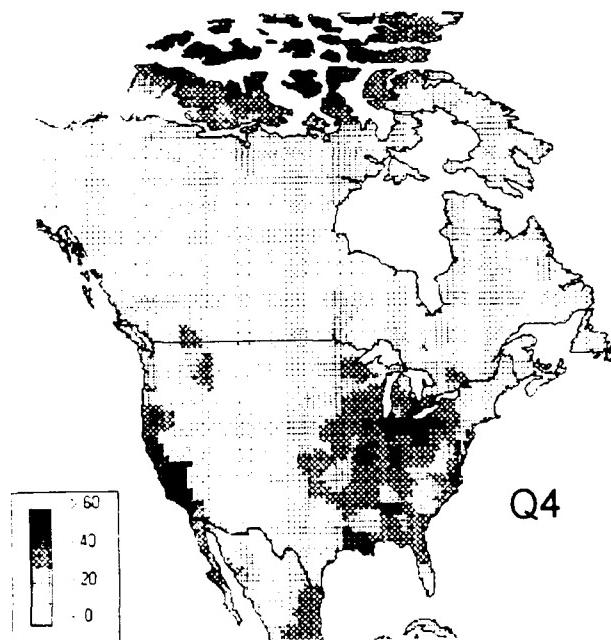
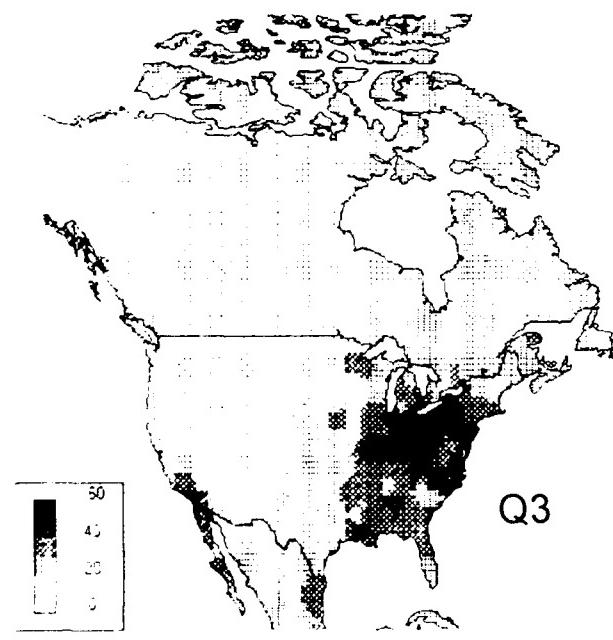
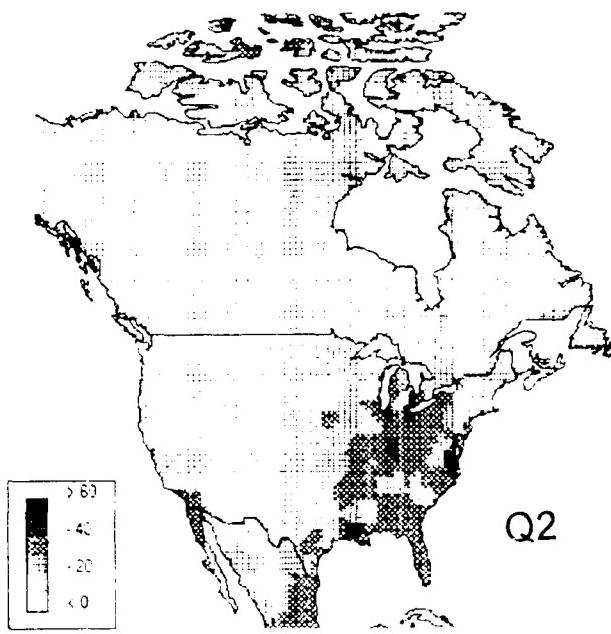
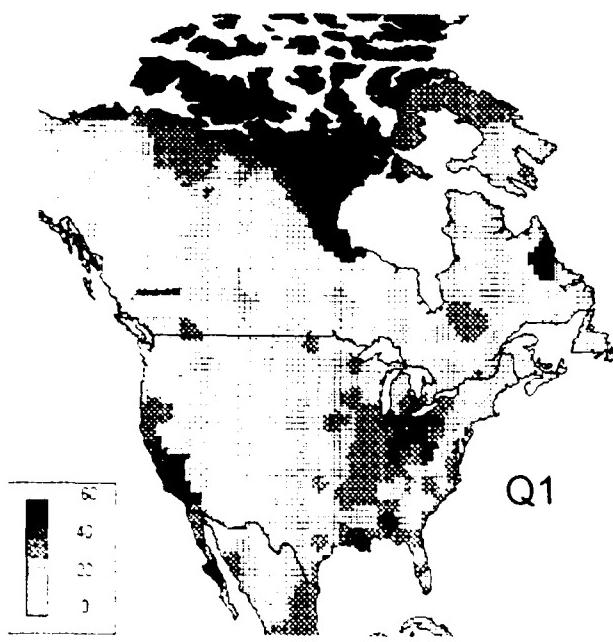


Figure 11 Quarterly maps representing filtered extinction coefficient for fog and precipitation, $F_{b\text{ext}}$, around 1980.

4. HAZE CLIMATE OF EUROPE

This section presents the spatial patterns of the three types of the extinction coefficient, raw b_{ext} , dry b_{ext} , and fully filtered b_{ext} . The spatial pattern of the fully filtered b_{ext} at the beginning of the 1970's and the beginning of the 1980's will also be examined. The details of data filtering procedures are described in our previous report to AF⁽⁵⁾.

Figures 12-14 present the quarterly maps, for the 75% b_{ext} averaged over the fourteen year time period for the raw b_{ext} , dry b_{ext} , and the fully filtered b_{ext} respectively. Inspection of the three sets of maps reveals a similar spatial pattern of the European extinction coefficient for the raw, dry, and filtered data. However, the absolute magnitude of the extinction coefficient decreases with each set of filtering performed on the data. The b_{ext} for the fully filtered data is about 20 to 50% lower than the b_{ext} for the raw data. The spatial pattern also reveals that this 20 to 50% difference is quite consistent over all geographic areas and all quarters.

The extinction maps show that the average b_{ext} is highest over Europe during quarter one (January, February, and March), and the lowest during quarter two (April, May, and June). Quarter four has a similar pattern to quarter one and quarter three resembles quarter two. In this sense the extinction coefficient over Europe could be lumped into a cold season (October-March), and the warm season (April-September).

After application of all of the data quality and meteorological filters the highest extinction coefficient is observed over Northern Italy. The Po River Valley is an industrial hot spot, and the cause of the high extinction coefficient there is undoubtedly man induced air pollution. Other areas of high extinction coefficient cover the "coal belt of Europe" stretching from southeastern Great Britain through Germany, and Poland. Another area of high extinction coefficient covers Romania and Bulgaria.

The spatial pattern of the fully filtered b_{ext} is averaged for five year time periods from 1973-77 and 1982-86 in Figures 15 and 16. As can be seen, there has been little change in the extinction coefficient throughout all of Europe for the summer quarters 2 and 3. However, during quarter one there was about a 20% increase in the light extinction

over the central and eastern part of Europe from the 1970's to the 1980's. A slight increase in b_{ext} is also apparent during the fourth quarter for this time period.

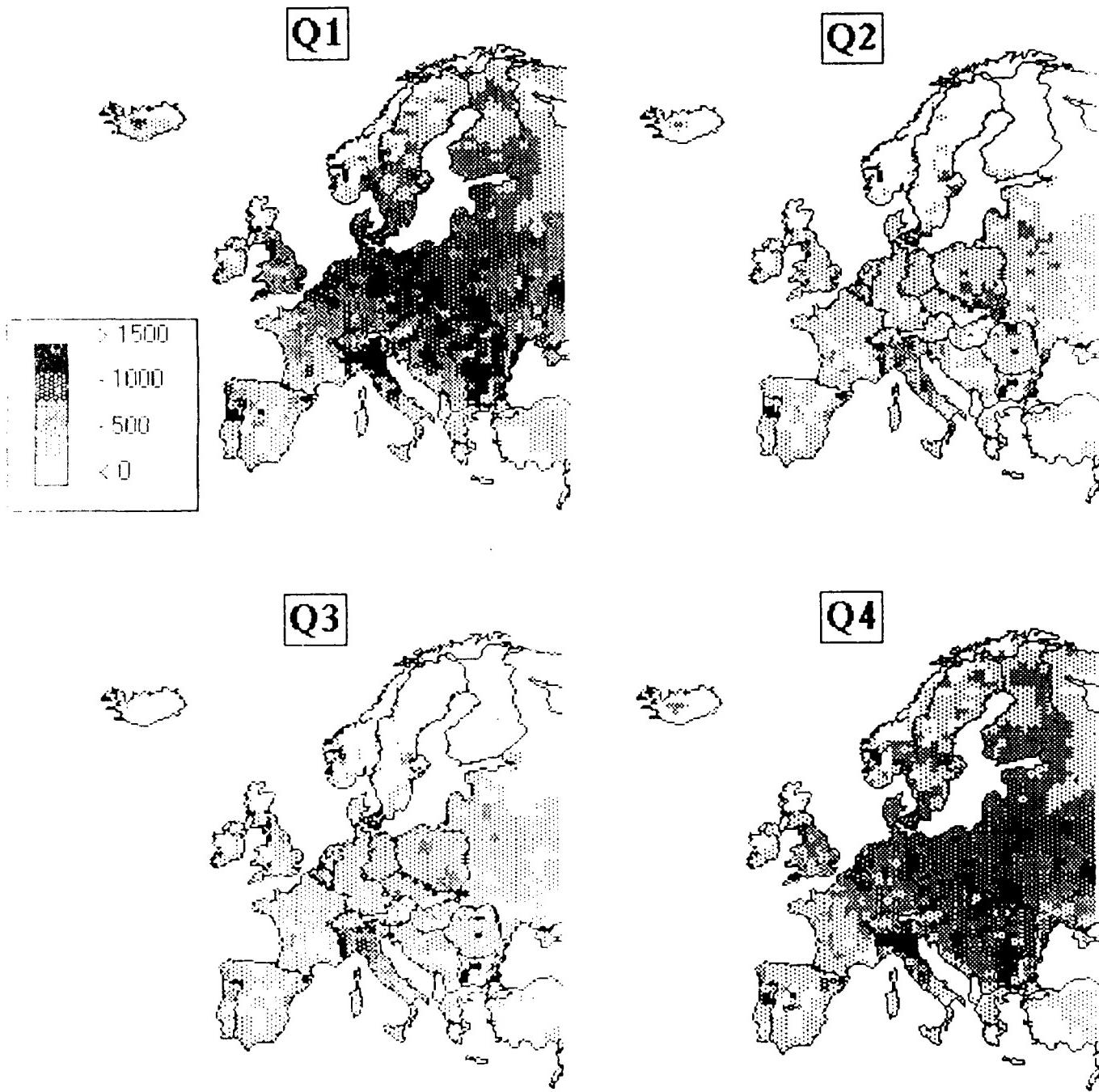


Figure 12 Quarterly maps presenting the 75% extinction coefficient (10^6 1/m) of the unfiltered data, averaged over the fourteen year time period (1973-86).

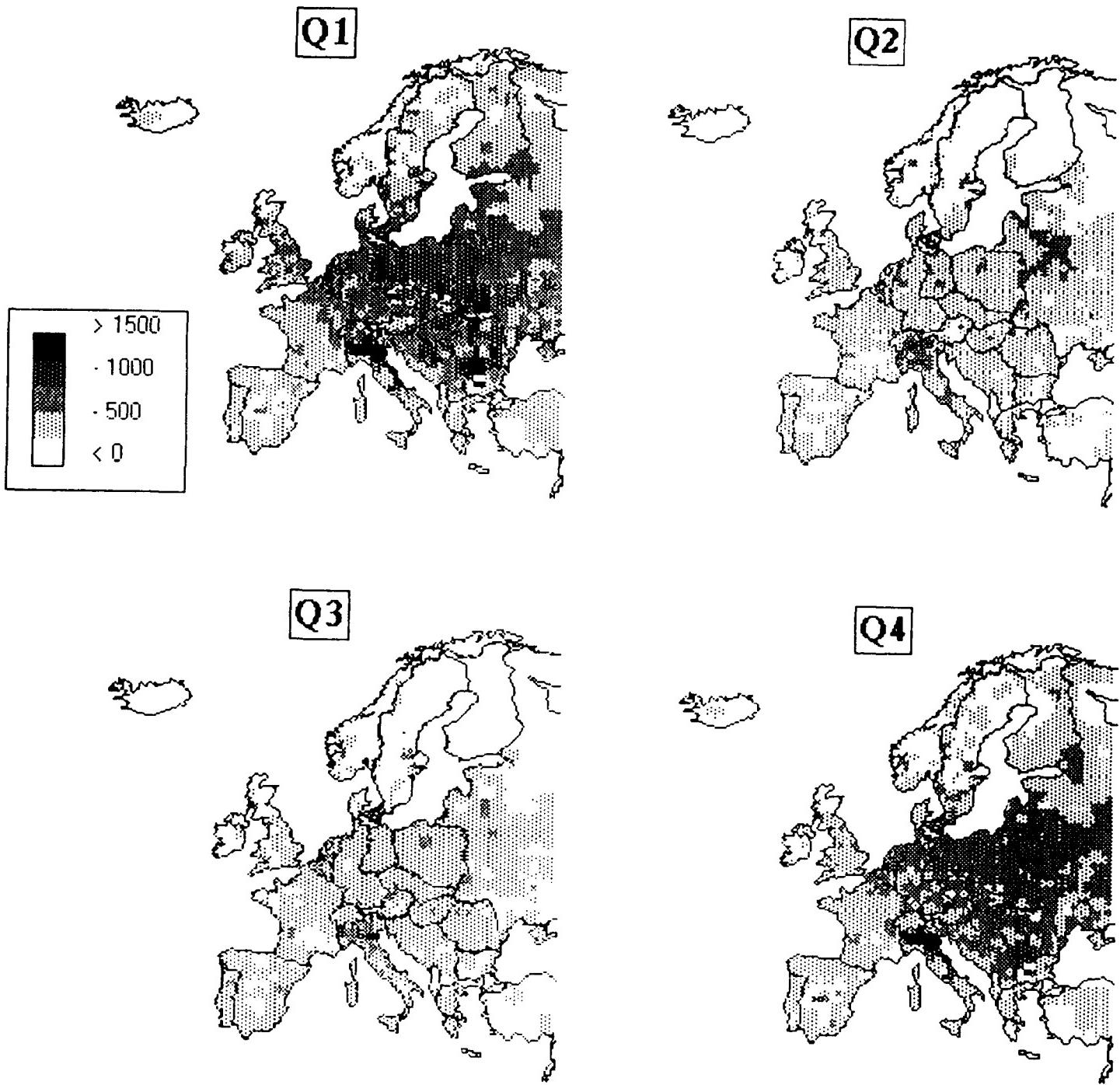


Figure 13 Quarterly maps presenting the 75% dry extinction coefficient (10^{-6} 1/m) averaged over the fourteen year time period (1973-86).

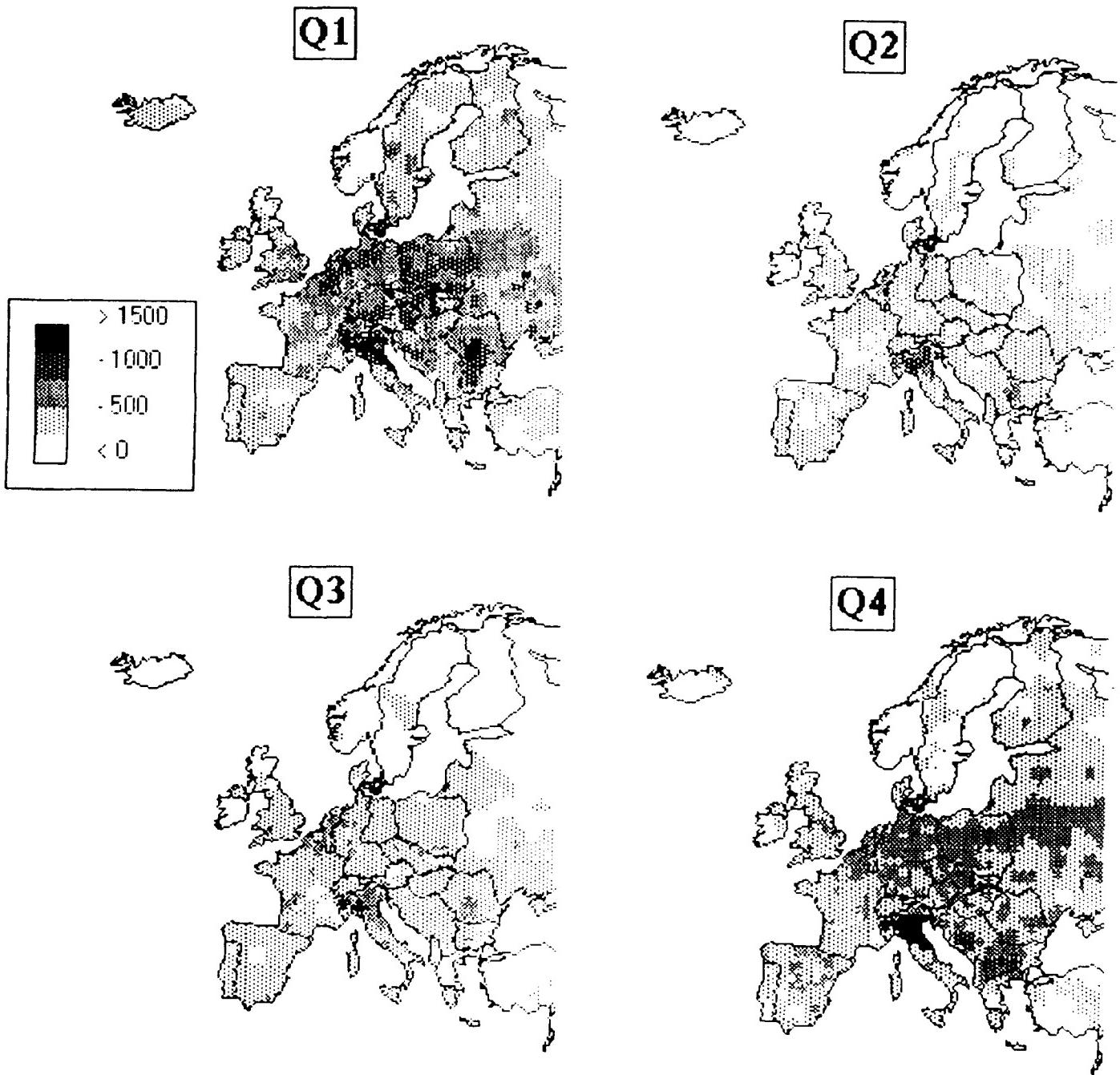


Figure 14 Quarterly maps presenting the 75% extinction coefficient (10^{-6} 1/m) of the fully filtered data, averaged over the fourteen year time period (1973-86).

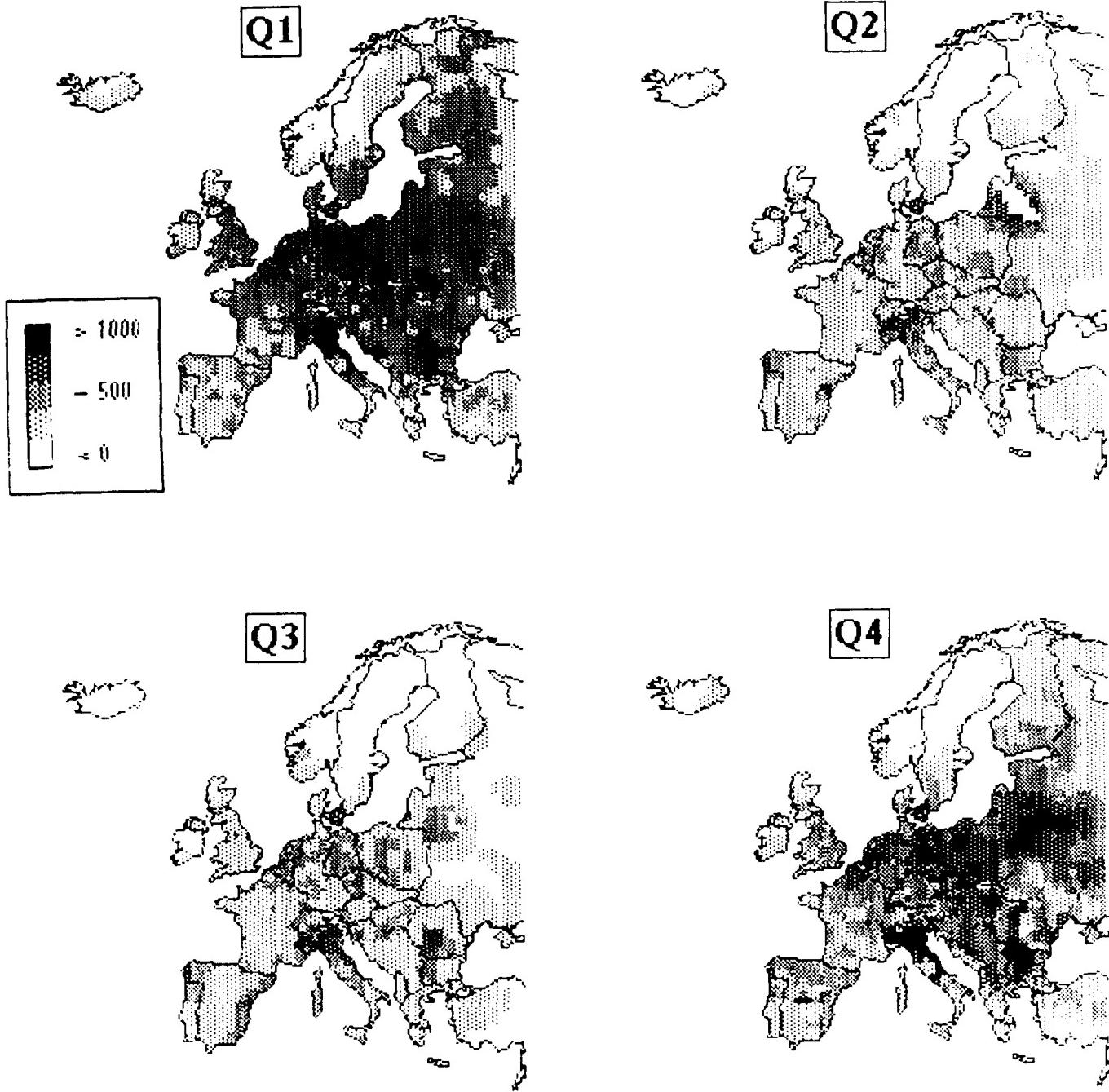


Figure 15 Quarterly maps presenting the 75% extinction coefficient (10^{-6} l/m) of the fully filtered data, averaged over the five year time period (1973-77).

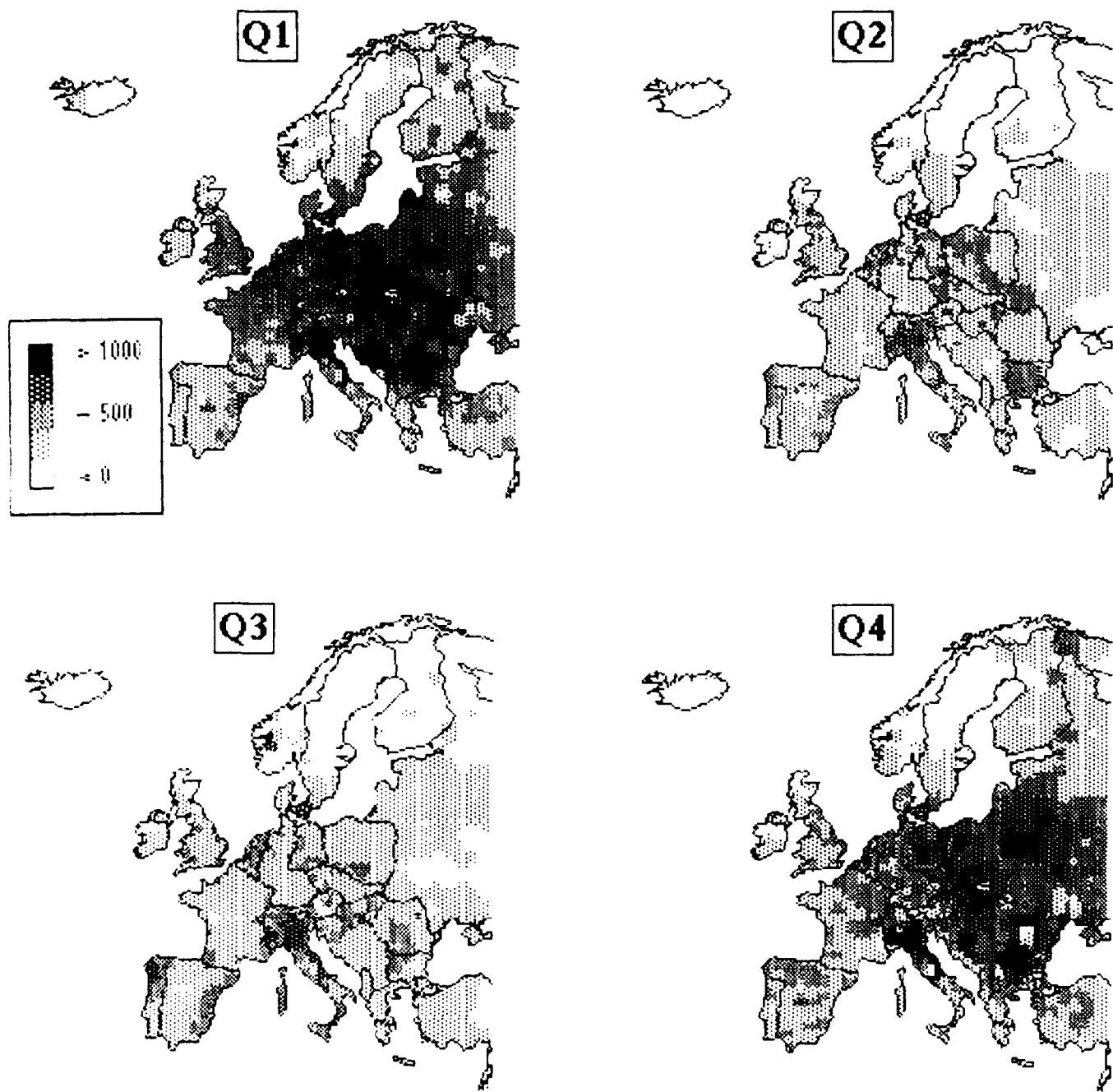


Figure 16 Quarterly maps presenting the 75% extinction coefficient (10^{-6} 1/m) of the fully filtered data, averaged over the five year time period (1982-86).

5. AEROSOL COMPOSITION OVER THE U.S.

The aerosol data in the NPS-NFPN and NESCAUM database were previously used to determine the concentrations of the major aerosol types throughout the U.S. on a seasonal basis⁽⁶⁾. In this section the results from this partitioning will be summarized.

The results of the partitioning of the quarterly averaged fine mass are presented in Figures 17-20. These figures depict the mass fractions of the different aerosol types for each station. The radius of each pie is dependent on the concentration of the fine mass. The sulfate, ammonium, and water have been added together, because normally in the atmosphere these three aerosol types are chemically linked. The unknown compound is the difference between the measured fine mass and the summation of the known aerosol types. It is speculated that the major constituent of the unknown is composed of nitrate compounds⁽⁶⁾.

As shown, there is a substantial increase, approximately 50%, in the mass concentration from the cold season, Q1 and Q4, to the warm season, Q2 and Q3, in the east and southwestern U.S.. The mass concentrations in the East, stations located east of the Mississippi, are larger than the West for all four quarters with the largest concentrations occurring during the third quarter where they can exceed $15 \mu\text{g}/\text{m}^3$. In the West, the mass concentrations are fairly uniform over the warm season, quarters 2 and 3 at about $4 \mu\text{g}/\text{m}^3$. However during the cold season, the Northwest generally has larger concentrations.

In the East, the fine aerosol mass is dominated by sulfur aerosol types (sulfate, ammonia, water) and organics. The sulfur aerosol types mass fraction is relatively constant for all four quarters constituting approximately 60% of the mass. The organics account for between 15 - 30% of the mass for each quarter. The remaining mass is primarily soot, salt, and soil.

In the Southwest, the sulfur aerosol types and organic generally constitute a smaller fraction of the fine mass than in the East, and are variable with season and space. The sulfur aerosols account for between 35 - 60% of the fine mass with the largest fraction occurring during quarters 3 and 4. The organics account for anywhere between 5 and 30% of the mass, with the largest fractions occurring during the cold seasons. Fine soil is also a

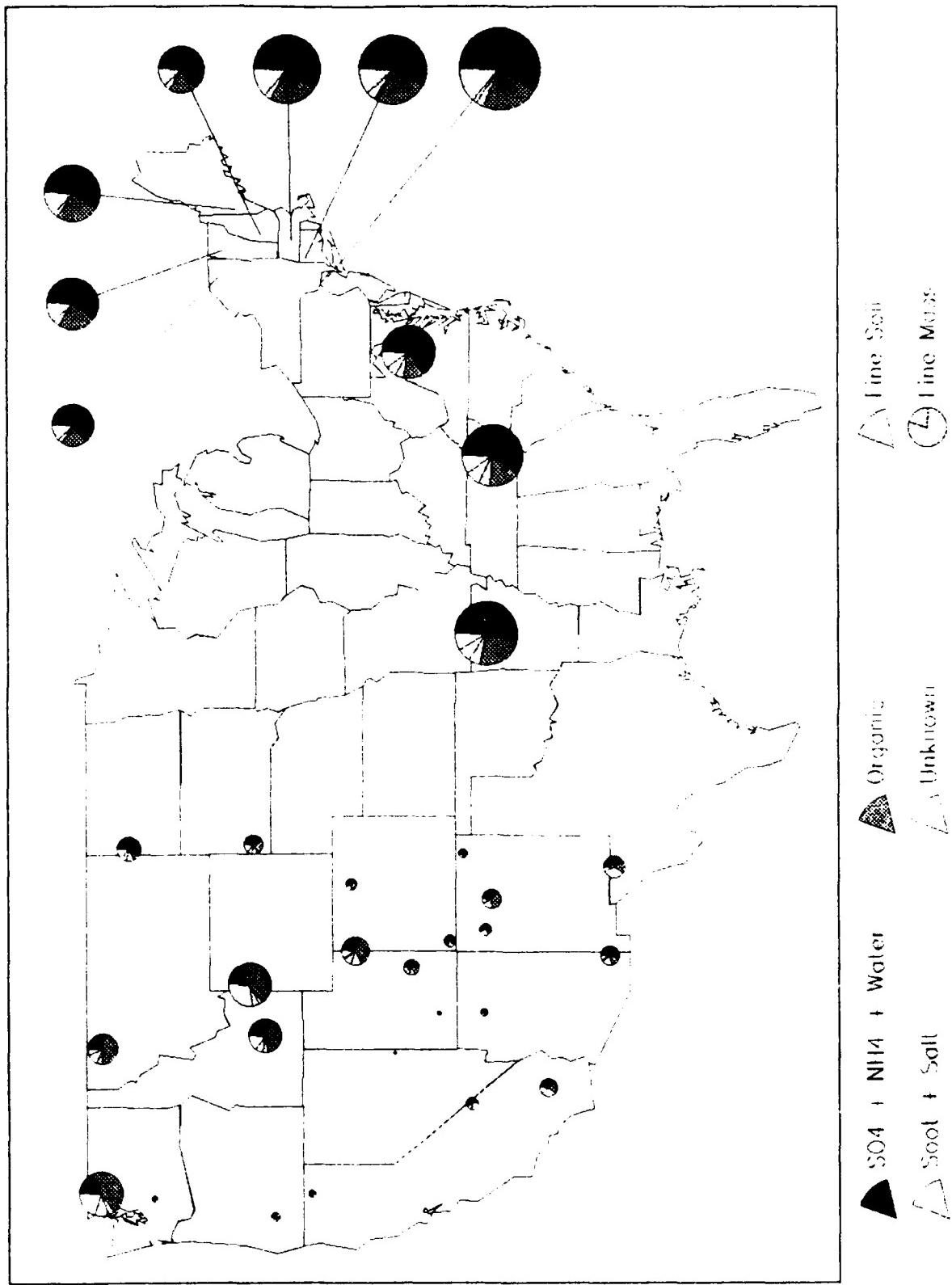


Figure 17 The mass fraction of each fine aerosol type at every location for quarter 1. The size of each pie chart is dependent on the fine mass concentration.

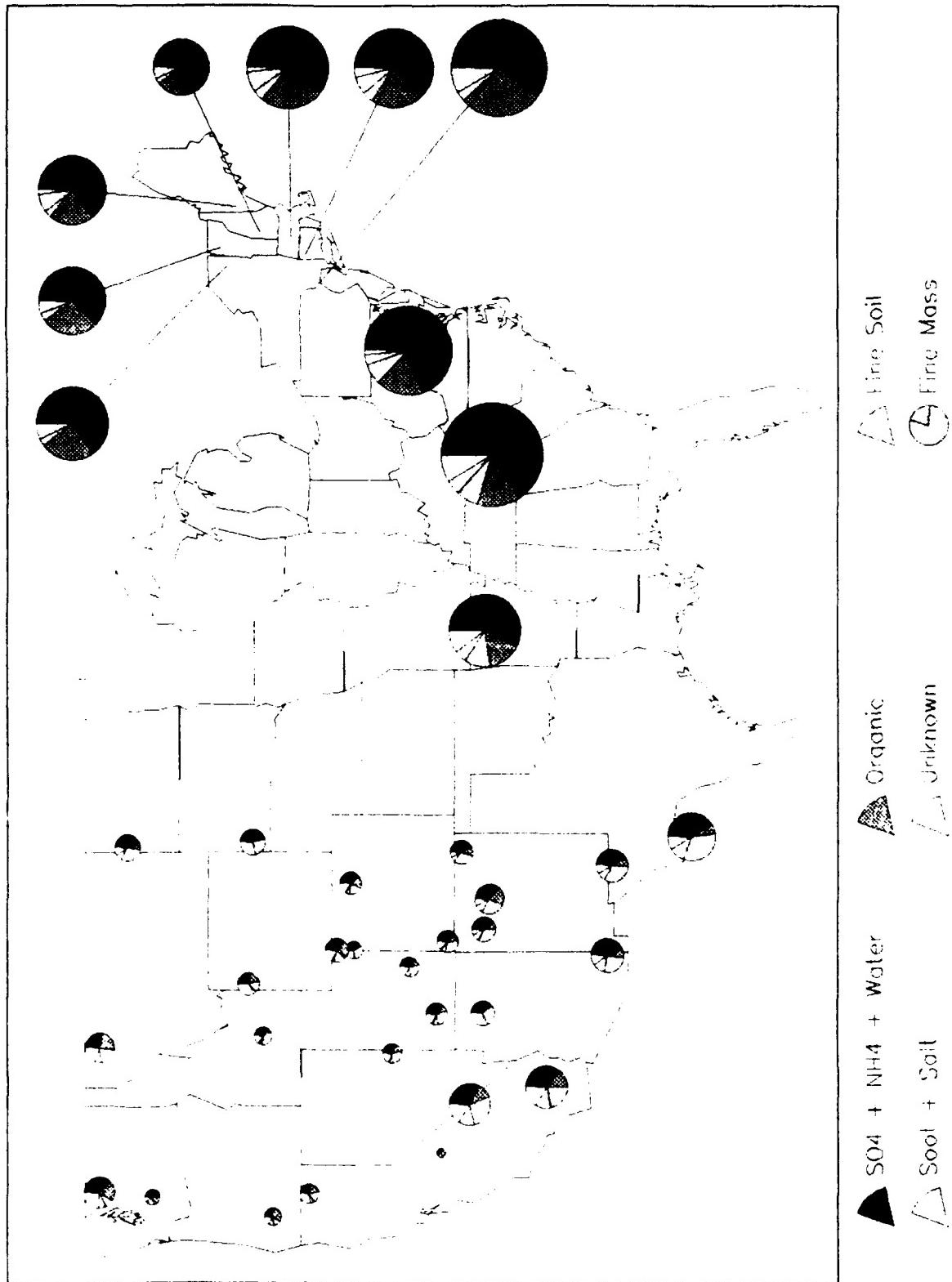


Figure 18 The mass fraction of each fine aerosol type at every location for quarter 2. The size of each pie chart is dependent on the fine mass concentration.

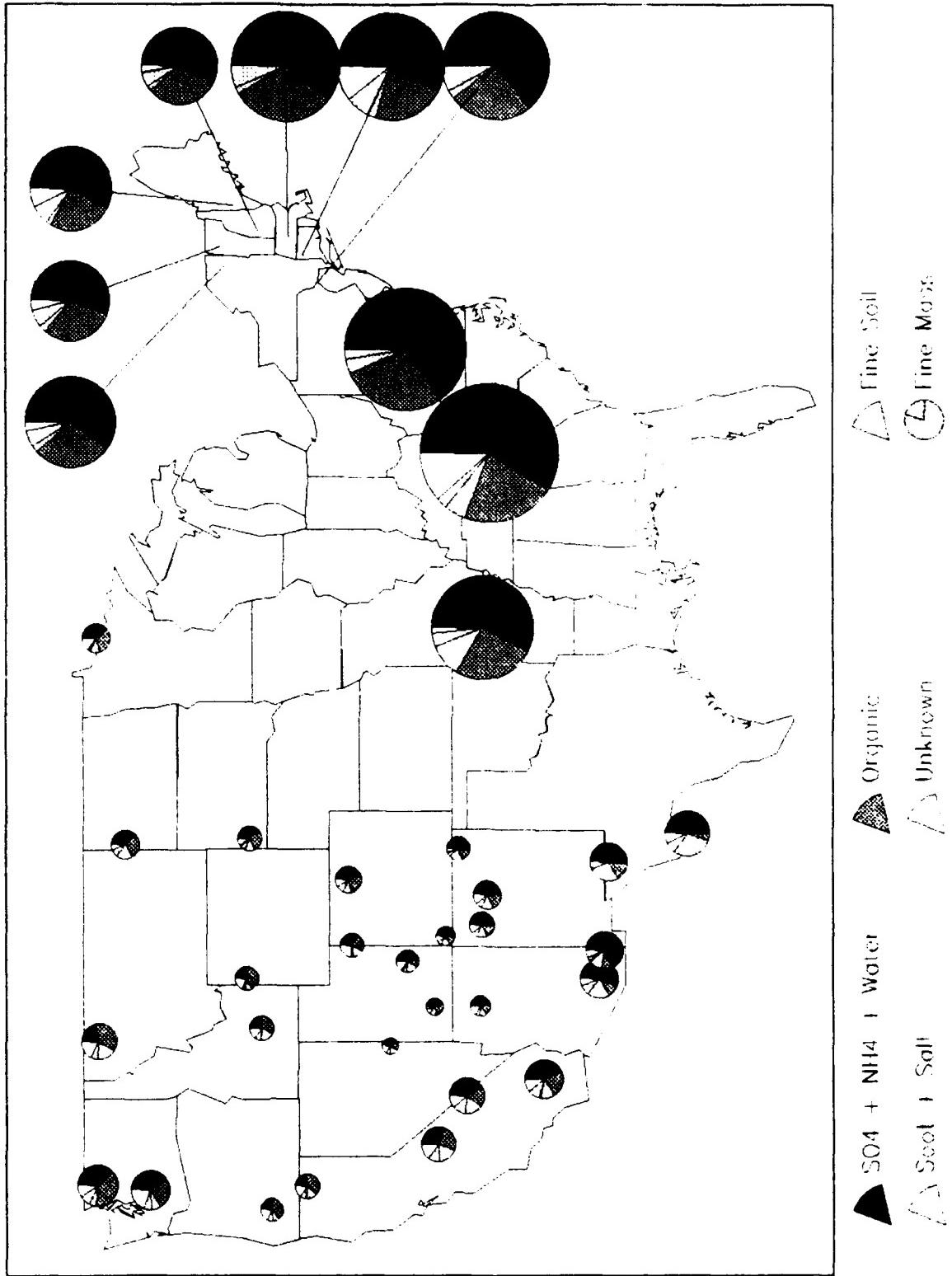


Figure 19 The mass fraction of each fine aerosol type at every location for quarter 3. The size of each pie chart is dependent on the fine mass concentration.

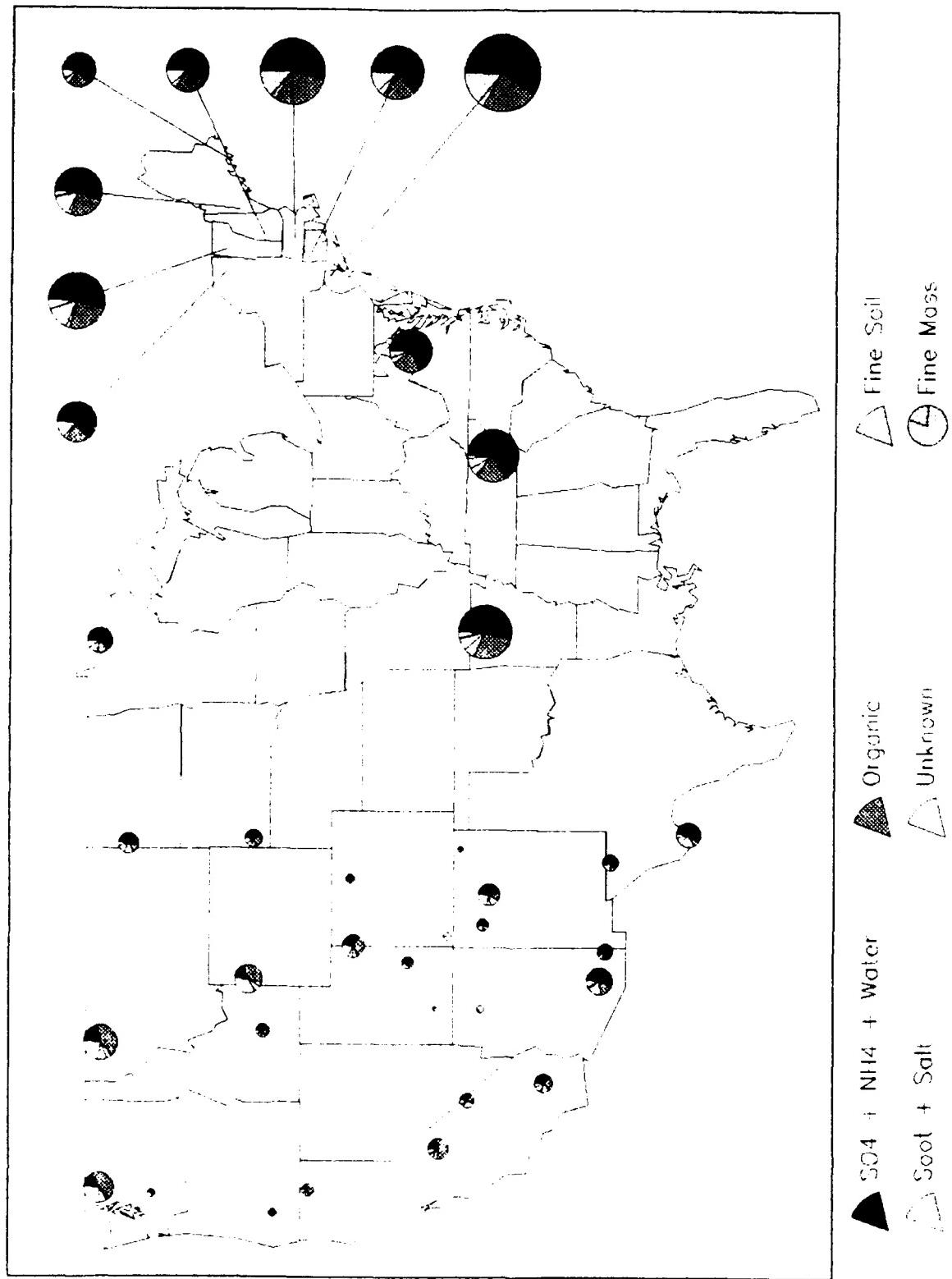


Figure 20 The mass fraction of each fine aerosol type at every location for quarter 4. The size of each pie chart is dependent on the fine mass concentration.

major component constituting between 25-30% of the fine mass. The maximum fraction of the soil aerosol occurs during the second quarter. The remaining mass is composed of mainly soot and salt. However, during the warm seasons there is a relatively large fraction of unknown, between 5 - 15%.

The northwestern region of the U.S. differs significantly from the rest of the country. Organics are the major aerosol type accounting for over 45% of the fine mass for a number of stations during the cold season. During the warm season this fraction decreases, but still generally constitutes for over 25% of the mass. The sulfur aerosol types mass fraction is largest during the warm season where it can account for up to 40%. The fine soil generally accounts for less of the fine mass than the sulfur aerosol types varying anywhere between 5 and 25%. This region contains the largest amount of "unknown" mass, approximately 20% on average, but can vary anywhere between 2 and 35%.

6. SUMMARY

This report describes the databases assembled for the project "*Climate and Properties of Atmospheric Aerosols*". This database description (metadata) is provided to aid the data usage by other researchers. Applications of the database include atmospheric transmission models (e.g. LOWTRAN), global change studies, air pollution studies, and general contribution to atmospheric sciences.

The four major aerosol databases include 1) Extinction coefficients for Europe (1977-1986) for 1,200 synoptic stations; 2)Extinction coefficient for North America (1948-1983)for 350 stations; 3) Aerosol mass and chemical composition data for 37 U.S. background stations; 4) Aerosol mass and chemical composition for the northeastern U.S.

These primary databases are augmented by array of derived (filtered, aggregated, reconciled) databases. The data are provided both in portable ASCII form, as well as in efficient binary form. The binary data are suitable for browsing by the Voyager data browser which is supplied with the data set.

7. APPENDIX

The visibility databases created from the North American and European surface synoptic meteorological data bases are presented below.

7.1 Available Data Sets

7.1.1 North American Light Extinction Data Sets

- BEXTAMER** : The extinction coefficient derived from over 300 surface synoptic weather stations throughout North America placed into the 25, 50, 75, and 90th distribution percentiles for each month. The data covers the time span from 1948 - 1983. Three forms of the b_{ext} exist: raw b_{ext} , meteorologically filtered b_{ext} and relative humidity corrected b_{ext} .⁽²⁾
- BEXTJAN** : A subset of the BEXTAMER data set containing only data for the month of January⁽²⁾.
- BEXTJUL** : A subset of the BEXTAMER data set containing only data for the month of July⁽²⁾.

7.1.2 European Light Extinction Data Sets

EURMETQ(1,2,3,4) : Contains meteorological variables for about 1600 surface synoptic weather stations in Europe, for fourteen years (1973-1986). The variables have been placed into the 10, 25, 50, 75, 90, 95th distribution percentiles for each quarter of the year. The variables are: Raw Visibility, Dry Extinction Coefficient, Temperature, Dew Point, Past Weather, Cloud Ceiling. The Dry Extinction Coefficient is the only variable which has been thoroughly tested, and we recommend that any calculations based on the visibility should be conducted using the Dry Extinction Coefficient⁽⁴⁾.

EURAWQ(1,2,3,4) : The raw 75% extinction coefficient averaged over the fourteen year time period (1973-1986) for each quarter of the year⁽⁴⁾.

EUMEFLQ(1,2,3,4) : The meteorological filtered (Dry) 75% extinction coefficient averaged over the fourteen year time period (1973-1986) for each quarter of the year⁽⁴⁾.

- EUFILETQ(1,2,3,4)** : The fully filtered 75% extinction coefficient averaged over the fourteen year time period (1973-1986) for each quarter of the year⁽⁴⁾.
- EUBX73Q(1,2,3,4)** : The fully filtered 75% extinction coefficient average over a five year time period (1973-1977) for each quarter of the year.
- EUBX82Q(1,2,3,4)** : The fully filtered 75% extinction coefficient average over a five year time period (1982-1986) for each quarter of the year.

U.S. Aerosol Chemical Data sets

- NPSAERS** : Contains the chemical aerosol data for the fine and coarse mass for 37 stations located in National Parks and Wilderness areas from January 1983 to June 1986⁽⁷⁾.
- NPSQUAVE** : The data from the NPSAERS data sets average for each quarter over the time period 1/1983 to 6/1986⁽⁷⁾.
- NESCAERS** : Contains the chemical aerosol data for the fine mass for 7 stations located in New England over the time period 9/1988 to 11/1991. This data set was used in the study where the aerosol mass was partitioned into its major constituent⁽⁷⁾. However, in that study the data spanned the time period 9/1988 to 11/1991.
- NESQUAVE** : The data from the NESCAERS data sets average for each quarter over the time period 9/1988 to 9/1990⁽⁷⁾.
- USAERTYP** : The quarterly average NPS-NFPN and NESCAUM chemical aerosol data sets partitioned into the major aerosol types⁽⁷⁾.

7.2 Data sets Descriptions

The sources and the gross features of visibility data have been extensively described in the past by many investigators dealing with the subject^(2,4,8,9). The following discussion will be limited to the description of the databases themselves.

The original databases which were used to create both the European and North American data sets originated from surface meteorological observations. They contained three hourly observations of all meteorological variables reported by synoptic stations. In all of the data sets, the visual range measurements were converted to the horizontal extinction coefficient, b_{ext} using the Koschmieder relationship; $b_{ext} = \log(C)/V$ where C is the Contrast threshold and V is the Visual range.

A problem with visual range measurements is that there is always a furthest marker beyond which the visual range is not resolved^(2,4). This translates to a lower threshold value for the computed extinction coefficient. For this reason, the mean is inappropriately biased upward, and more reliable, nonparametric statistical indices are more useful. In all of the data sets the meteorological variables have been placed into distribution percentiles. Other statistical quantities such as means and standard deviations can be computed from the percentiles once it is established which percentile is valid, i.e. above the threshold.

7.2.1 Data Formats

The data sets come in two different formats with several accompanying files. One format, the data format, contains the raw data in ASCII form. The data resides in the file with the extension .DAT. Along with this data is a data dictionary which describes the layout of the data file. The data dictionary has the same name as the data file, but has the extension .DAD. A location table is provided which gives the name, latitude, and longitude of each location. Each location is identified by a location code, in both the location table and data file. The location file has the extension .LCT.

The other format of the data is the Voyager format. Voyager is a data exploration software by Lantern Corporation. It was developed under the guidance of the principal investigator of this project. Voyager data viewer is supplied with the database. It can be freely distributed with this database. In order to browse the data using this software, the Voyager Viewer must be installed onto the computer. See the accompanying Voyager Viewer manual for the installation instructions. The Voyager files contain all of the same data as the data files. These files can be identified by the extension .VOY. An accompanying file is the Voyager workbook. This file is identified by the extension .WKB, and must be located in the same directory as the Voyager file. Voyager also needs the correct map files to operate. These files are identified by the extensions .BDR, and .MPD, and are located with the Voyager file.

7.2.1 North American Light Extinction Data sets

The North American visibility data sets consist of over 300 stations and spans the time period 1948-1983. The location of each site is depicted in Figure 1. The raw visibility observations were converted into noontime light extinction coefficient using a

contrast threshold of 0.02 in the Koschmieder equation. Three different extinction coefficients were calculated: the first set includes all visibility data regardless of weather and pollutant conditions (b_{ext}); the second group (Fb_{ext}) is composed of extinction coefficients excluding precipitation (rain and snow) and fog events; the third group (RHb_{ext}) excludes precipitation, fog, and also an RH correction was performed to compensate for water and vapor effects.⁽²⁾ This latter parameter is closely related to the dry fine particle aerosol mass concentration.

7.2.1.1 BEXTAMER

This data set contains the three forms of the extinction coefficient, (raw b_{ext} , b_{ext} -meteorologically filtered b_{ext} , Fb_{ext} , and the RH corrected b_{ext} , RHb_{ext}) for all sites in North America. The data were placed in the 25, 50, 75, and 90th distribution percentiles for each month. In Figures 21-24 the trends of the raw extinction coefficient are presented for several sites located throughout the U.S.

The raw ASCII data for this data set resides in the file **BEXTAMER.DAT**. Provided with this file is the data dictionary **BEXTAMER.DAD** which has been reproduced in Table 1. Also supplied with this data set is the location table **BEXTAMER.LCT** which lists the location name, latitude, longitude, and the location code, **LOC_CODE**.

Table 1. The data dictionary for the BEXTAMER.DAT data file.

Variables	Units	String Length	Null Identifier
LOC_CODE	--	3 CHAR	""
YEAR	--	2 NUM	-1
MONTH	--	2 NUM	-1
Bext25	10^{-5} 1/m	3 NUM	-1
Bext50	10^{-5} 1/m	3 NUM	-1
Bext75	10^{-5} 1/m	3 NUM	-1
Bext90	10^{-5} 1/m	3 NUM	-1
Fext25	10^{-5} 1/m	3 NUM	-1
Fext50	10^{-5} 1/m	3 NUM	-1
Fext75	10^{-5} 1/m	3 NUM	-1
Fext90	10^{-5} 1/m	3 NUM	-1
Rext25	10^{-5} 1/m	3 NUM	-1
Rext50	10^{-5} 1/m	3 NUM	-1
Rext75	10^{-5} 1/m	3 NUM	-1
Rext90	10^{-5} 1/m	3 NUM	-1

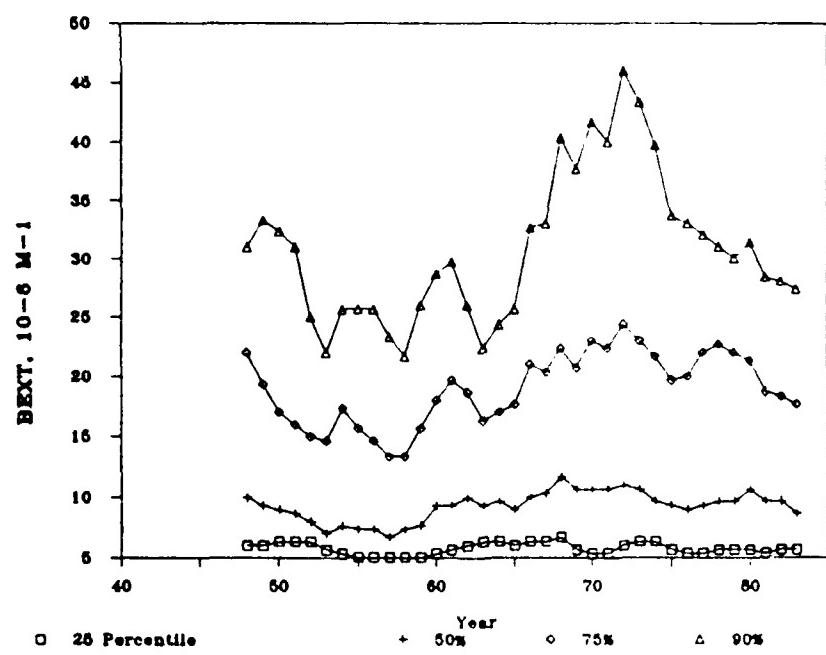
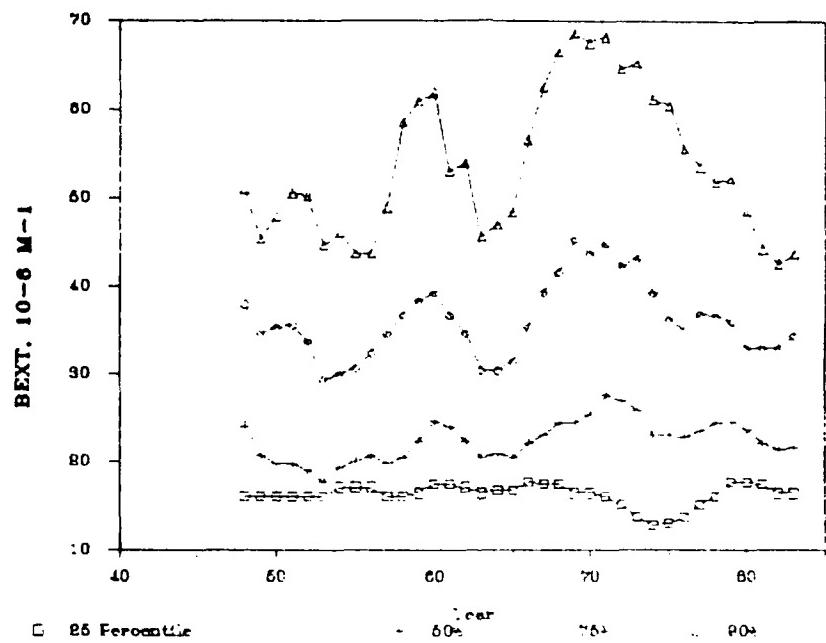


Figure 21 Trend of haziness in New York, NY (top) and Burlington, VT (bottom).

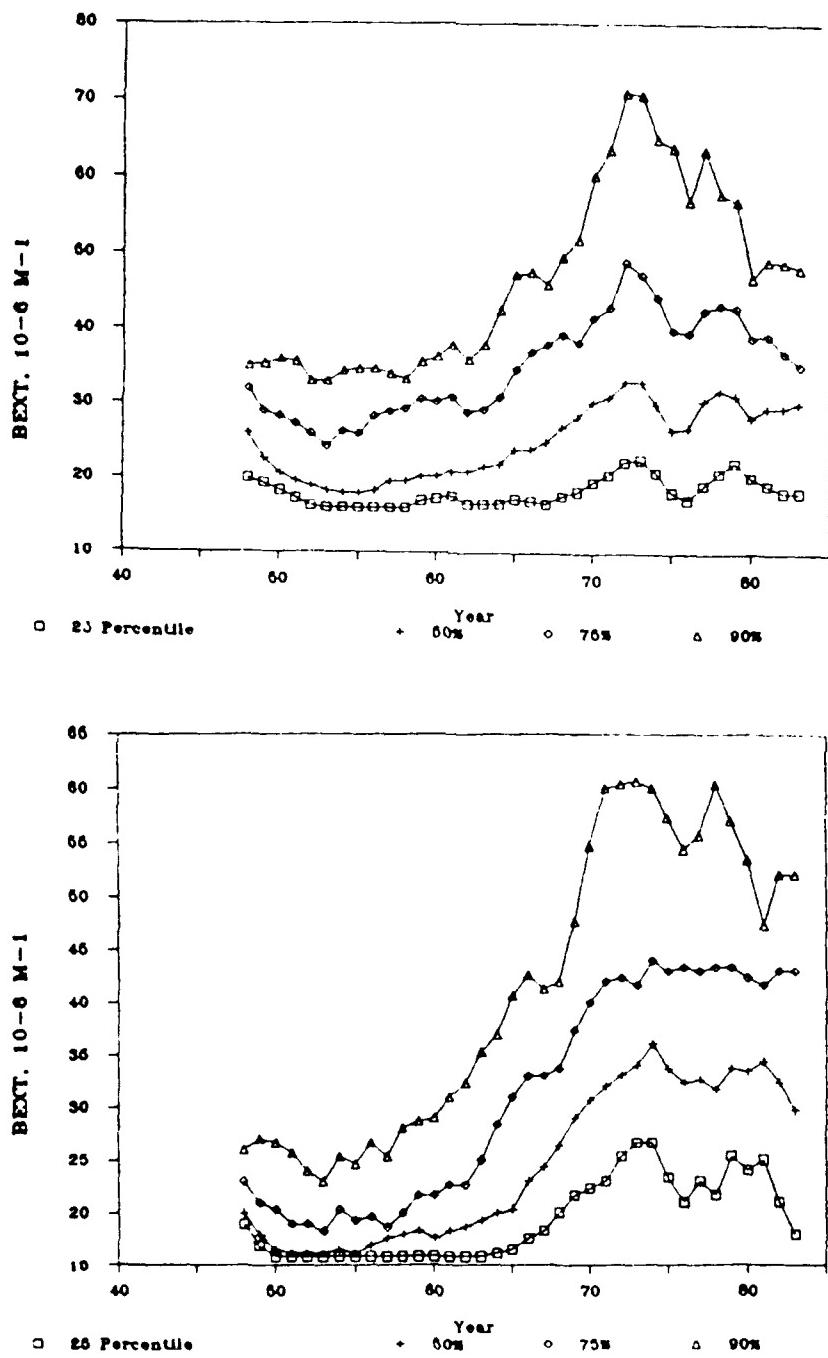


Figure 22 Trend of haziness in Columbus, OH (top) and Charlotte, NC (bottom).

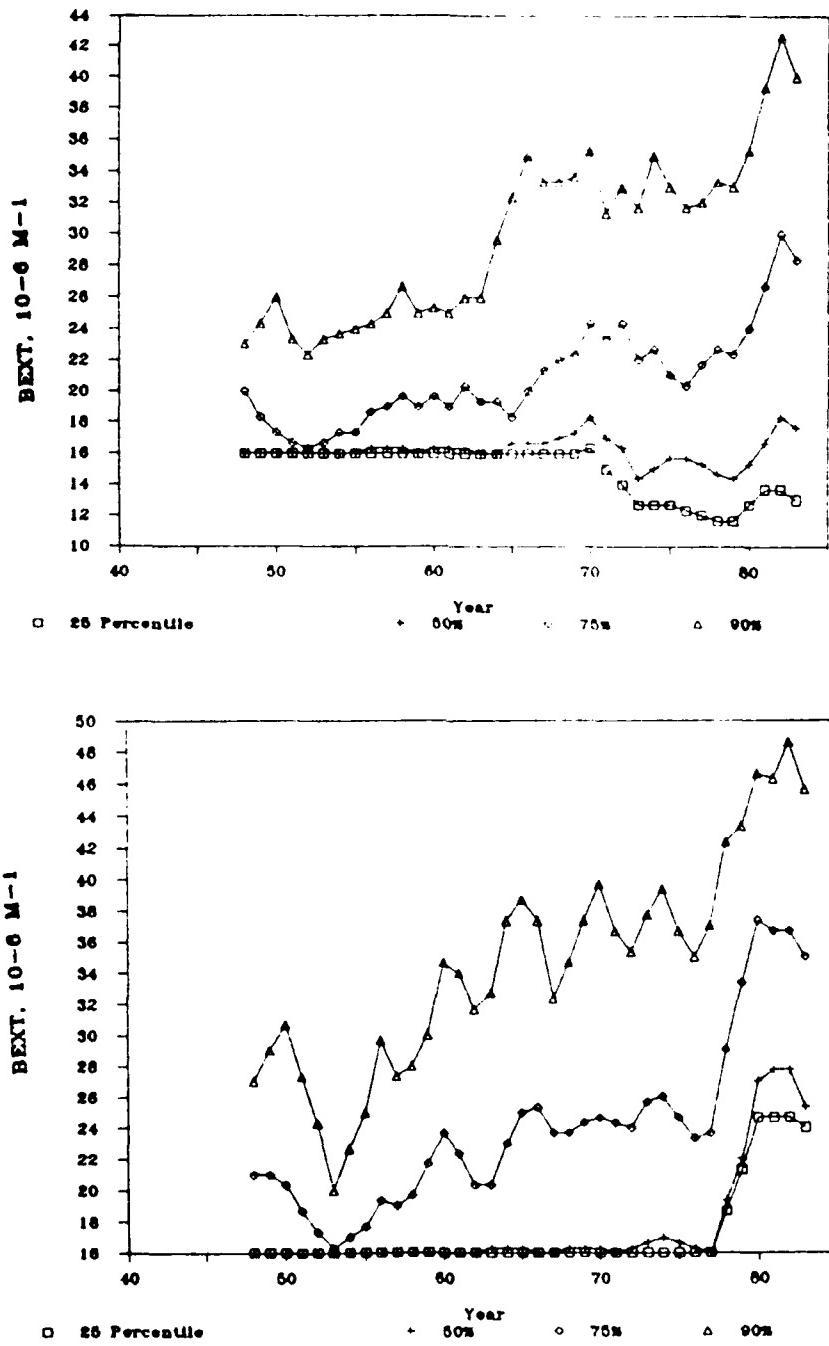


Figure 23 Trend of haziness in Des Moines, IA (top) and Madison, WI (bottom).

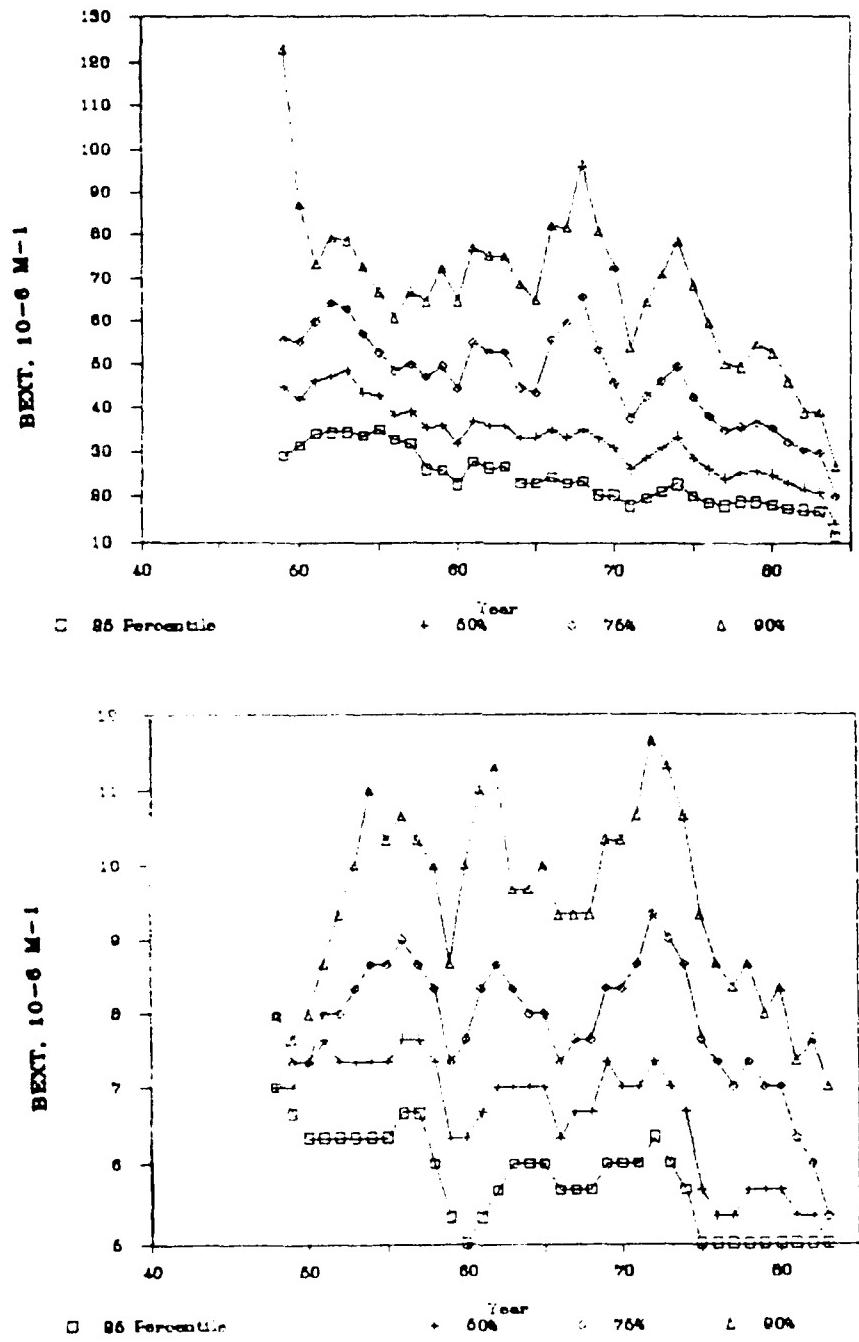


Figure 24. Trend of haziness in Long Beach, CA (top) and Phoenix, AZ (bottom).

The Voyager file for this data set is called **BEXTAMER.VOY**. Figures 25 and 26 present the front end of the Voyager browser displaying the three dimensions, space, time, variables, of the **BEXTAMER**. data set.

7.2.1.2 BEXTJAN and BEXTJUL

These two data sets are simply subsets of **BEXTAMER** containing only the data for the month January, **BEXTJAN.DAT**, and the data for July, **BEXTJUL.DAT**. The data dictionary for these data sets is located in Table 2. The location Table is identical to that for the **BEXTAMER** data and is called **BEXTJAN.LCT** and **BEXTJUL.LCT**. Voyager files for each data set exist in the files **BEXTJAN.VOY** and **BEXTJUL.VOY**. Figures 25-26 presents the Voyager Browser displaying these data sets in various forms.

Table 2. The data dictionary for the BEXTJAN.DAT and BEXTJUL.DAT data files.

Variables	Units	String Length	Null Identifier
LOC_CODE	--	7 CHAR	""
MONTH	--	4 NUM	-999
dummy2	--	1 CHAR	""
DAY	--	2 NUM	-999
dummy3	--	1 CHAR	""
YEAR	--	4 NUM	-999
BX25	10^{-5} l/m	7 NUM	-999
BX50	10^{-5} l/m	7 NUM	-999
BX75	10^{-5} l/m	7 NUM	-999
BX90	10^{-5} l/m	7 NUM	-999
FX25	10^{-5} l/m	7 NUM	-999
FX50	10^{-5} l/m	7 NUM	-999
FX75	10^{-5} l/m	7 NUM	-999
FX90	10^{-5} l/m	7 NUM	-999
RX25	10^{-5} l/m	7 NUM	-999
RX50	10^{-5} l/m	7 NUM	-999
RX75	10^{-5} l/m	7 NUM	-999
RX90	10^{-5} l/m	7 NUM	-999

7.2.2 European Light Extinction Data Sets

The original European data set consisted of fourteen years of meteorological data (1973-1986) for about 1600 stations in Europe. The location of each site is depicted in Figure 2. This data set was extracted from the DATSAV global weather database maintained by the U.S. Air Force, ETAC, Scott Air Force Base, IL.

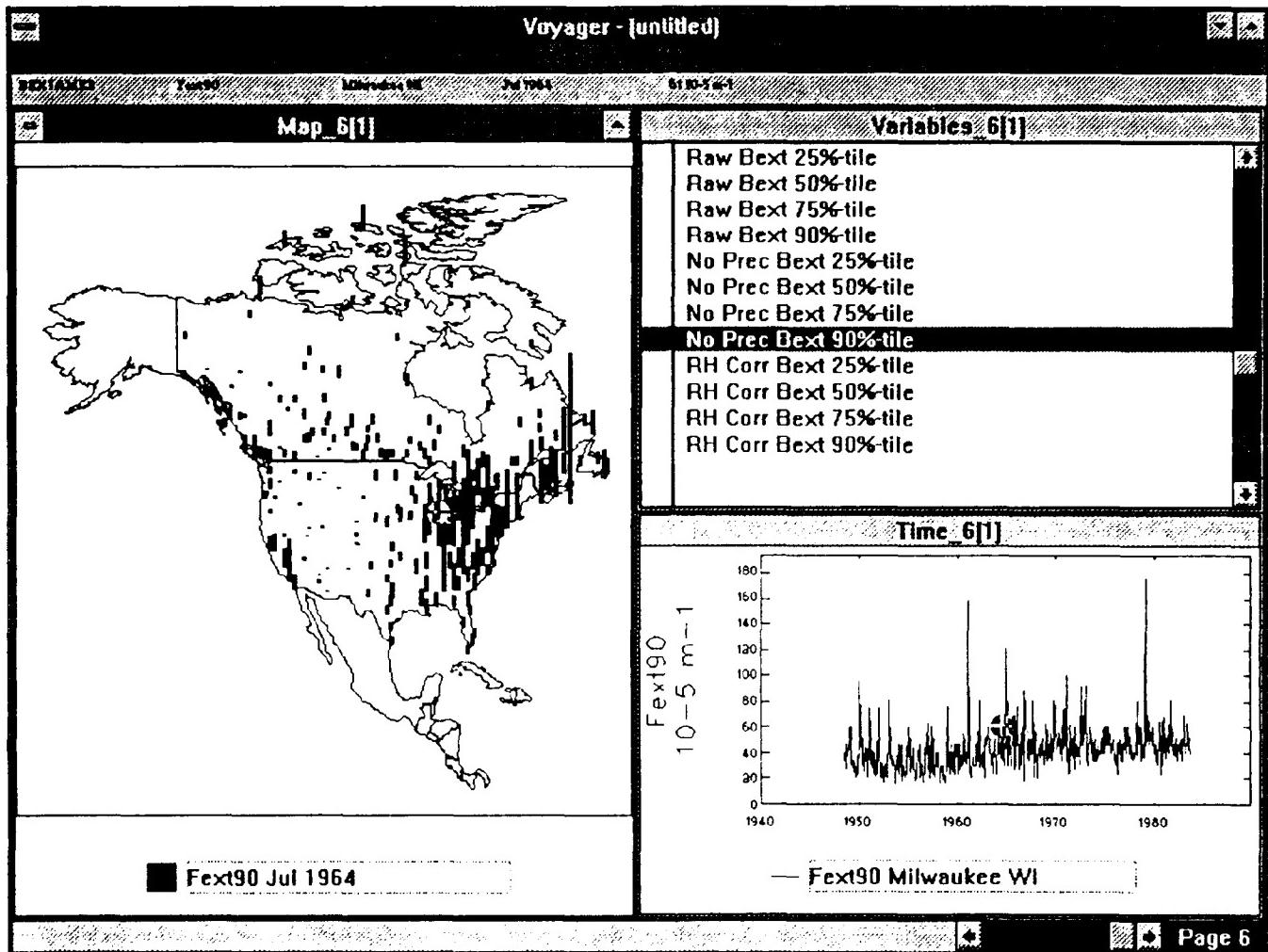


Figure 25 Voyager data browser workspace showing linked Map, Time, and Variables views of the BEXTAMER database.

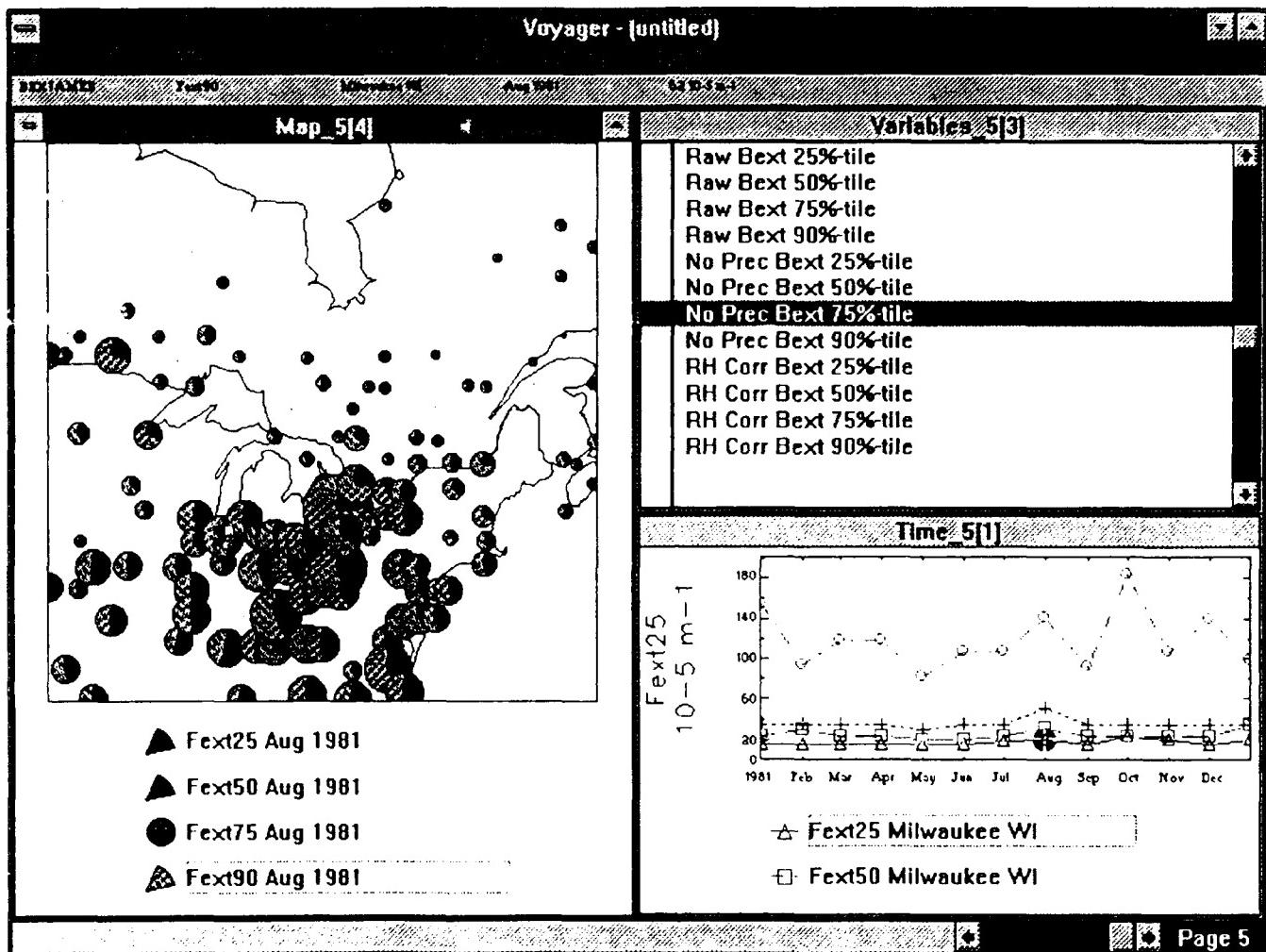


Figure 26 A zoomed in view of the database in Figure 25.

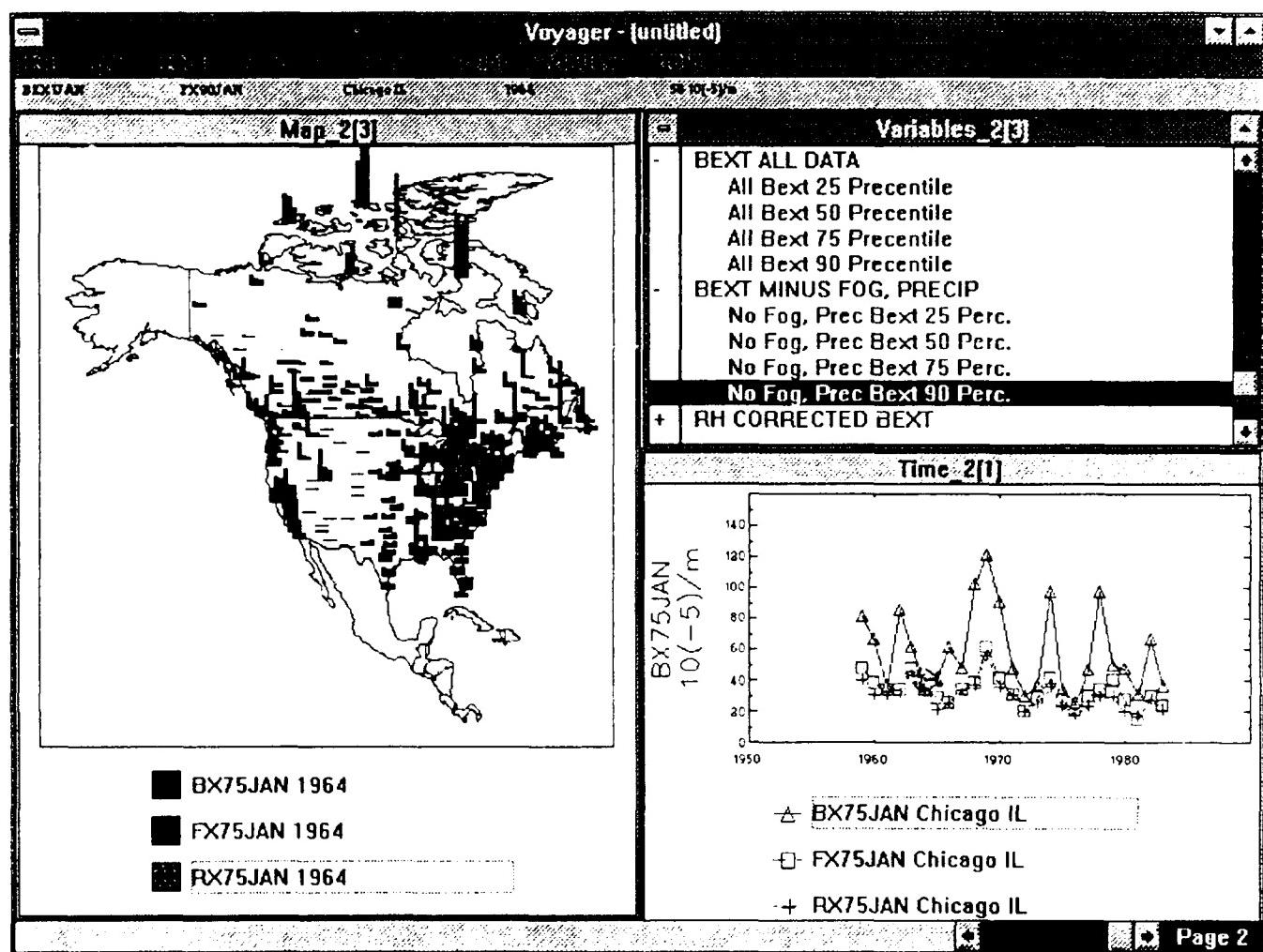


Figure 27 Voyager data browser views for the BEXJAN database.

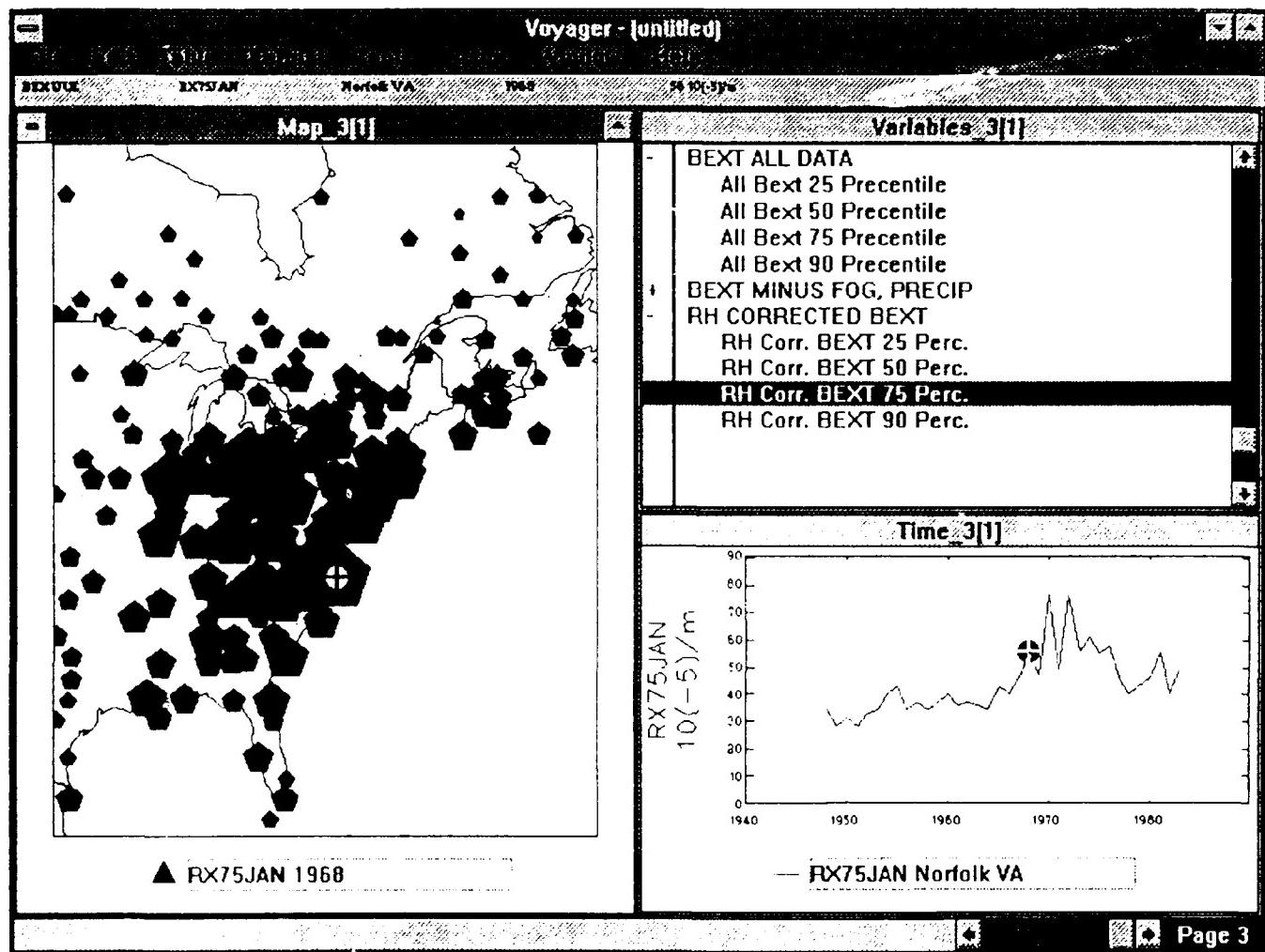


Figure 28 Voyager data browser views for the BEXJUL database.

A data set consisting of a subset of the meteorological variables was created from the extracted DATSAV data. In this data set, the noontime visual range from the DATSAV data set was converted into a dry extinction coefficient, dry b_{ext} , using a contrast threshold of 3.0 in the Koschmieder equation. The dry b_{ext} was created by excluding visual range measurements taken during precipitation or fog. The data was then placed into the 10th, 25th, 50th, 75th, 90th, and 95th cumulative distribution percentiles for each quarter of the year. Quarter 1 begins in January. The data for each quarter has been separated out into different files. The following data sets present the raw data before and after aggregation and filtering processes were conducted on the data. Note, only the extinction coefficient has been verified. All other meteorological variables are meant for background information. Any calculations performed using the visibility data should be based on the extinction coefficients, and not the visibility data.

7.2.2.1 EURMETQ(1,2,3,4)

The **EURMETQ(1,2,3,4)** data set consists of a separate file for each quarter of the year. The raw ASCII data resides in the files: **EURMETQ1.DAT**, **EURMETQ2.DAT**, **EURMETQ3.DAT**, and **EURMETQ4.DAT**. Where the last two characters in the file name represent the quarter of the year the data file is associated with. For example **Q1** is for quarter 1. Each data file contains the meteorological variables, Temperature, Dew Point, Past Weather, Cloud Ceiling, Visibility, and Dry Extinction. In these data files, the Dry Extinction Coefficient is the only variable which has been thoroughly tested, and we recommend that any calculations based on the visibility should be conducted using the Dry Extinction Coefficient.

Provided with the ASCII data files are the data dictionaries, **EURMETQ(1,2,3,4).DAD**. The data dictionaries are identical for each file, Table 3. The location table is located in the file **EURMETQ(1,2,3,4).LCT**. Voyager files for each data set exist in the files **EURMETQ(1,2,3,4).VOY**. Figure 29 presents the Voyager browser displaying these data sets in various forms.

7.2.2.2 EURAWQ(1,2,3,4)

EURAWQ(1,2,3,4) is a group of four files, one for each quarter, which contains the data for the raw 75% extinction coefficient over the fourteen year period (1973-1986)

for each quarter of the year. The ASCII data is located in the files **EURAWQ(1,2,3,4).DAT** while the data dictionary and location tables are in the files **EURAWQ(1,2,3,4).DAD** and **EURAWQ(1,2,3,4).LCT** respectively. The data dictionary is reproduced in the Table 4. A Voyager file does not exist for this data set.

7.2.2.3 EUMEFLQ(1,2,3,4)

EUMEFLQ(1,2,3,4) is a group of four files, one for each quarter, which contains the meteorologically filtered (dry) 75% extinction coefficient averaged over the fourteen year period (1973-1986) for each quarter of the year. The ASCII data is located in the files **EUMEFLQ(1,2,3,4).DAT** while the data dictionary and location tables are in the files **EUMEFLQ(1,2,3,4).DAD** and **EUMEFLQ(1,2,3,4).LCT** respectively. The data dictionary follows the same format as that in Table 4. A Voyager file does not exist for this data set.

Table 3. The data dictionary for the EURMETQ(1,2,3,4).DAT data files.

Variable	Units	String Length	Null Identifier
LOC_CODE	--	6 CHAR	" "
YEAR	--	2 NUM	-1
Month	--	2 NUM	-1
Tmp10	K*10	4 NUM	-1
Tmp25	K*10	4 NUM	-1
Tmp50	K*10	4 NUM	-1
Tmp75	K*10	4 NUM	-1
Tmp90	K*10	4 NUM	-1
Tmp95	K*10	4 NUM	-1
DewPt10	K*10	4 NUM	-1
DewPt25	K*10	4 NUM	-1
DewPt50	K*10	4 NUM	-1
DewPt75	K*10	4 NUM	-1
DewPt90	K*10	4 NUM	-1
DewPt95	K*10	4 NUM	-1
PastWx10	*Code	2 NUM	-1
PastWx25	*Code	2 NUM	-1
PastWx50	*Code	2 NUM	-1
PastWx75	*Code	2 NUM	-1
PastWx90	*Code	2 NUM	-1
PastWx95	*Code	2 NUM	-1
CIG10	m	6 NUM	-1
CIG25	m	6 NUM	-1
CIG50	m	6 NUM	-1
CIG75	m	6 NUM	-1
CIG90	m	6 NUM	-1
CIG95	m	6 NUM	-1
Visib25	km	2 NUM	-1
Visib10	km	2 NUM	-1
Visib25	km	2 NUM	-1
Visib50	km	2 NUM	-1
Visib75	km	2 NUM	-1
Visib90	km	2 NUM	-1
Visib95	km	2 NUM	-1
DryExt10	10^{-6} l/m	6 NUM	-1
DryExt25	10^{-6} l/m	6 NUM	-1
DryExt50	10^{-6} l/m	6 NUM	-1
DryExt75	10^{-6} l/m	6 NUM	-1
DryExt90	10^{-6} l/m	6 NUM	-1
DryExt95	10^{-6} l/m	6 NUM	-1

* The meaning of coded values is found in the DATSAV HANDBOOK⁽⁷⁾

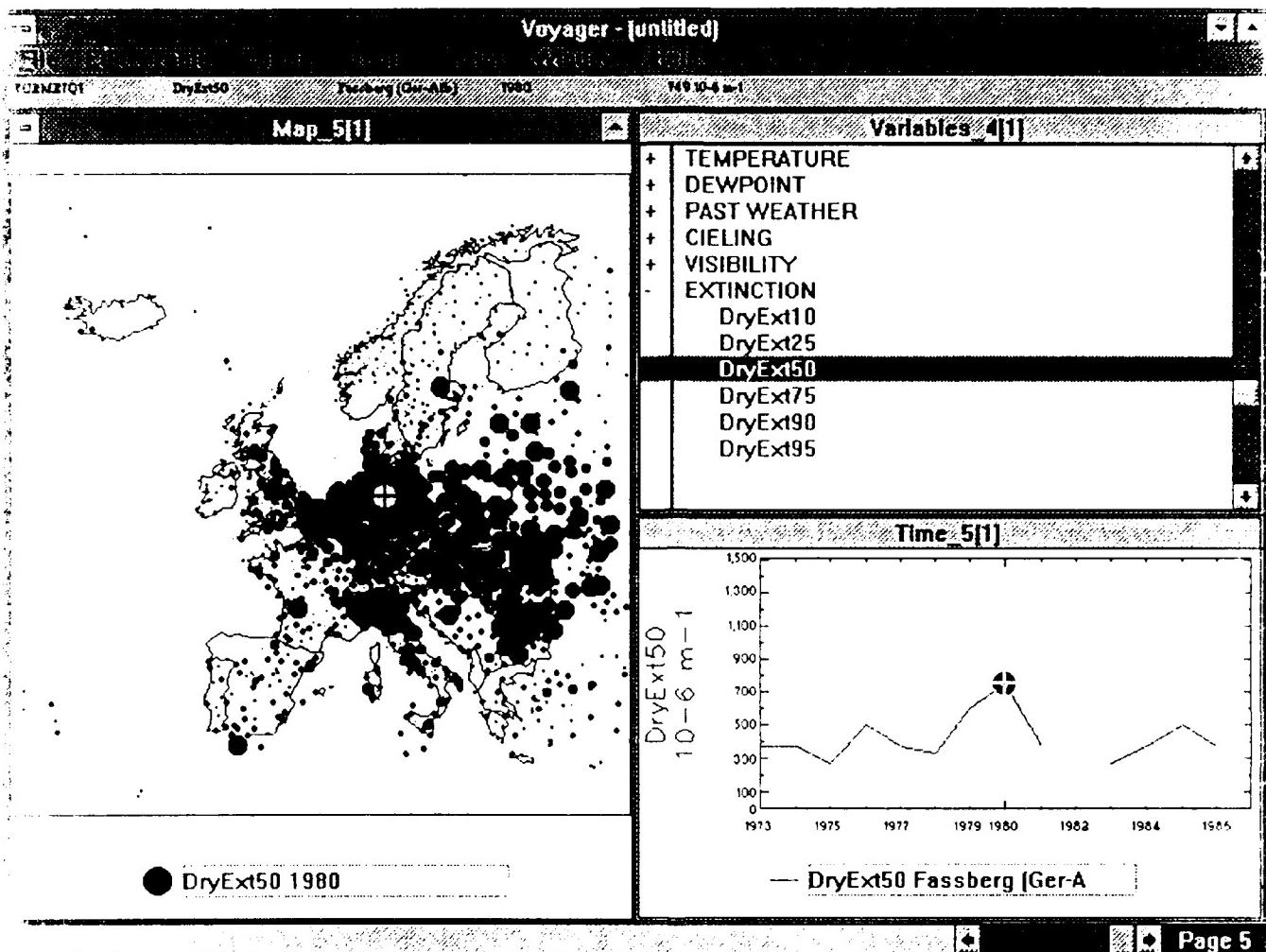


Figure 29 Voyager data browser views for the EURMETQ1 database.

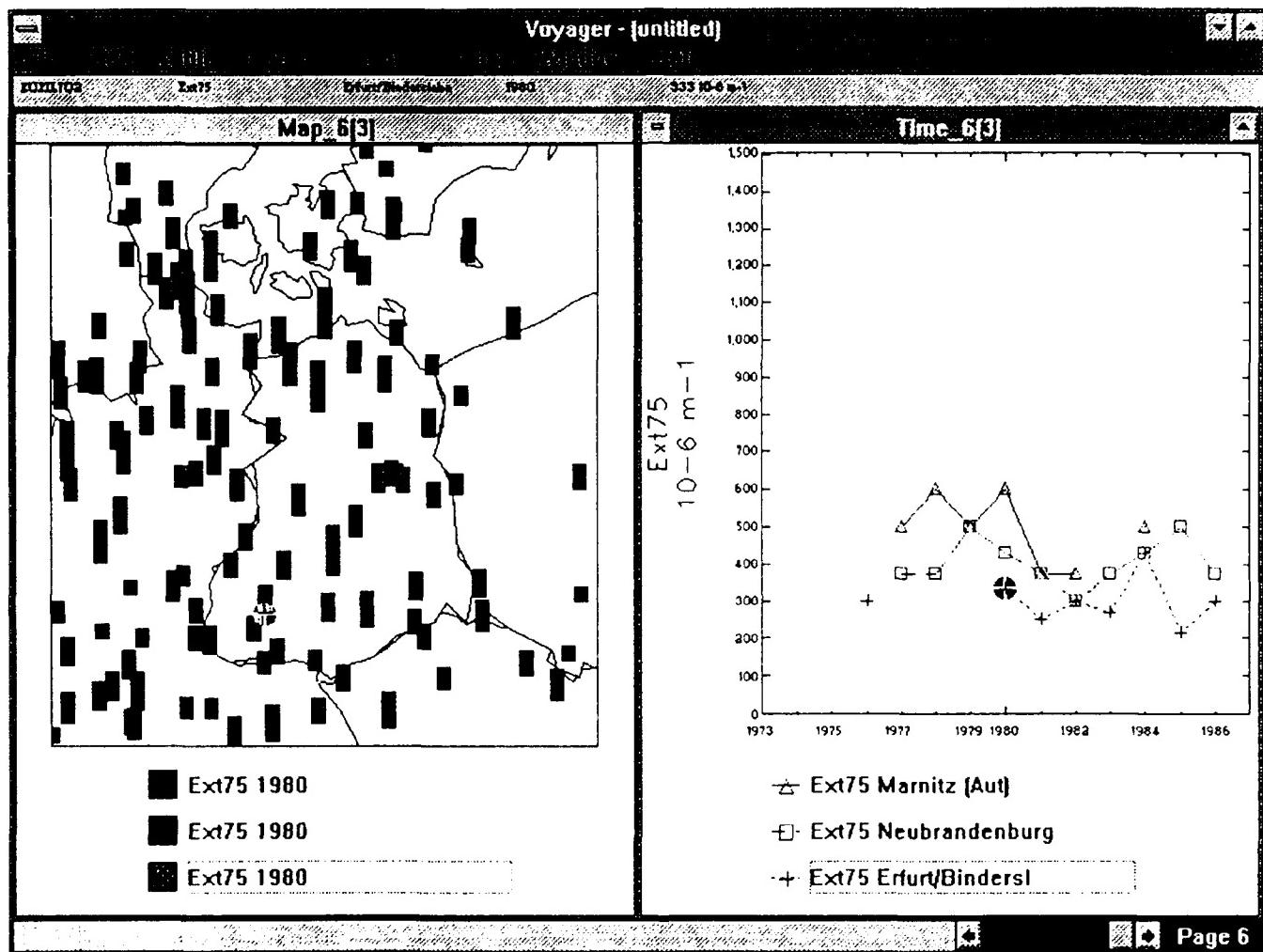


Figure 30 Voyager data browser views for the EUFILTQ2 database.

Table 4. The data dictionary for the EURMETQ(1,2,3,4).DAT data files.

Variable	Units	String Length	Null Identifier
LOC_NAME	--	42 CHAR	""
LOC_LAT	Radians	12 NUM	.9999
LOC_LON	Radians	12 NUM	.9999
FiltBx75	10^{-6} 1/m	17 NUM	.9999

7.2.2.4 EUFILETQ(1,2,3,4)

EUFILETQ(1,2,3,4) is a group of four files, one for each quarter, which contains the fully filtered⁽⁴⁾ data for the 75% extinction coefficient over the fourteen year period (1973-1986) for each quarter of the year. The ASCII data is located in the files **EUFILETQ(1,2,3,4).DAT** while the data dictionary and location tables are in the files **EUFILETQ(1,2,3,4).DAD** and **EUFILETQ(1,2,3,4).LCT** respectively. The data dictionary follows the same format as that in Table 4. The Voyager file for this data set can be found in the file named **EUFILETQ(1,2,3,4).VOY**. Figure 30 presents the Voyager map and time view for this data set.

7.2.2.5 EUBX73Q(1,2,3,4)

EUBX73Q(1,2,3,4) is a group of four files, one for each quarter, which contains the fully filtered⁽⁴⁾ data for the 75% extinction coefficient over a five year period (1973-1977) for each quarter of the year. The ASCII data is located in the files **EUBX73Q(1,2,3,4).DAT** while the data dictionary and location tables are in the files **EUBX73Q(1,2,3,4).DAD** and **EUBX73Q(1,2,3,4).LCT** respectively. The data dictionary follows the same format as that in Table 4. A Voyager file does not exist for this data set.

7.2.2.6 EUBX82Q(1,2,3,4)

EUBX82Q(1,2,3,4) is a group of four files, one for each quarter, which contains the fully filtered⁽⁴⁾ data for the 75% extinction coefficient over a five year period (1982-1986) for each quarter of the year. The ASCII data is located in the files **EUBX82Q(1,2,3,4).DAT** while the data dictionary and location tables are in the files

EUBX82Q(1,2,3,4).DAD and **EUBX82Q(1,2,3,4).LCT** respectively. The data dictionary is follows the same format as that in Table 4. A Voyager file does not exist for this data set.

7.2.3 U.S. Aerosol Chemical Data sets

7.2.3.1 NPSAERS

The **NPSAERS** data set originated from the National Park Service - National Fine Particle Network, NPS - NFPN database. The NPS-NFPN database consisted of 37 stations located across the continental U.S., Figure 3. All of the samplers were located inside national parks and wilderness areas far from any urban centers, industrial sources, and highways. Inside the parks the samplers were kept away from roads, parking lots, and chimneys. The NPS-NFPN network contains data from 1982 to June 1986. However, over this time period stations were added and removed form the network. However, most of the stations contained data from January 1983 to June 1986.

Two samples each week were collected over a 72 hour duration using the AeroVironment SFS-500 samplers. The aerosol samplers collected both fine and coarse particles with approximately a 50% cut off ratio at $2.5 \mu\text{m}$ ⁽⁵⁾. The samples were analyzed for the fine mass, hydrogen, optical absorption, and elemental concentrations for sodium to lead.

This data was used to partition the fine and coarse mass into the major aerosol types⁽⁷⁾. The data resides in the Voyager file **NPSAERS.VOY**. A data file has not been provided with this database. Note, all values less than zero are values that were below the minimum detectable limit.

7.2.3.2 NPSQUAVE

This data set contains the quarterly averages of chemical aerosol data in the file **NPSAERS**. The averages for each quarter were calculated over the time period 1/1983 to 6/1986. Any data value that was below the minimum detectable limit, negative numbers in **NPSAERS.VOY**, were discarded. This potentially biases the averages high especially for the trace elements. The Voyager file resides in the file **NPSQUAVE.VOY**. No data file

is provided. This data was used to partition the fine and coarse mass into the major aerosol types for each season.⁽⁷⁾

7.2.3.3 NESCAERS

The **NESCAERS** data was derived from the NESCAUM network. This monitoring network consists of seven stations located in the Northeast of the U.S., Figure 3. These sites are located in rural locations which were found to be consistent with EPA, NPS, and IMPROVE siting criteria⁽⁶⁾. The data spans a two year time period September 1988 to December 1991. This network is still in operation.

The fine particles were sampled for a 24 hour duration on every Wednesday, Saturday, and every 6th day. The fine particles were separated from the aerosol using a U. C. Davis cyclone sampler, and collected on Teflon filters mounted in nucleopore cassettes. This cyclone had a 50% capture efficiency for particles 2.5 μm in diameter at a flow rate of 23 l/min. This data was used to partition the fine mass into the major aerosol types for each season in New England using the data over the time span 9/1988-9/1990⁽⁷⁾.

The Voyager file is found in the file **NESCAERS.VOY**. No data file has been provided.

7.2.3.3 NESQUAVE

The data from the **NESCAERS** data sets average for each quarter over the entire time period of the data set (9/88 to 9/90). This data was used to partition the fine mass into the major aerosol types for each season in New England⁽⁷⁾.

The Voyager file is found in the file **NESCAERS.VOY**. No data file has been provided.

7.2.3.4 USAERTYP

This data set contains the results from the partitioning of the aerosol mass into the major aerosol types for each quarter of the year using the NPS-NFPN and NESCAUM databases⁽⁷⁾. The data set contains the variables Fine Mass, Fine Sulfate, Fine Ammonium, Fine water, Fine Soot, Fine Salt, Fine Soil, Fine Organics, and the

Unknown fine mass. This data set exist only as a Voyager file, and is found in the file
USAERTYP.VOY.

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